CANADA
DEPARTMENT OF MINES
MINES BRANCH
HON. W. TEMPLEMAN, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER;
EUGENE HAANEL, PH.D., DIRECTOR.

CHRYSOTILE-ASBESTOS

ITS OCCURRENCE, EXPLOITATION, MILLING, AND USES

BY

Fritz Cirkel, M.E.

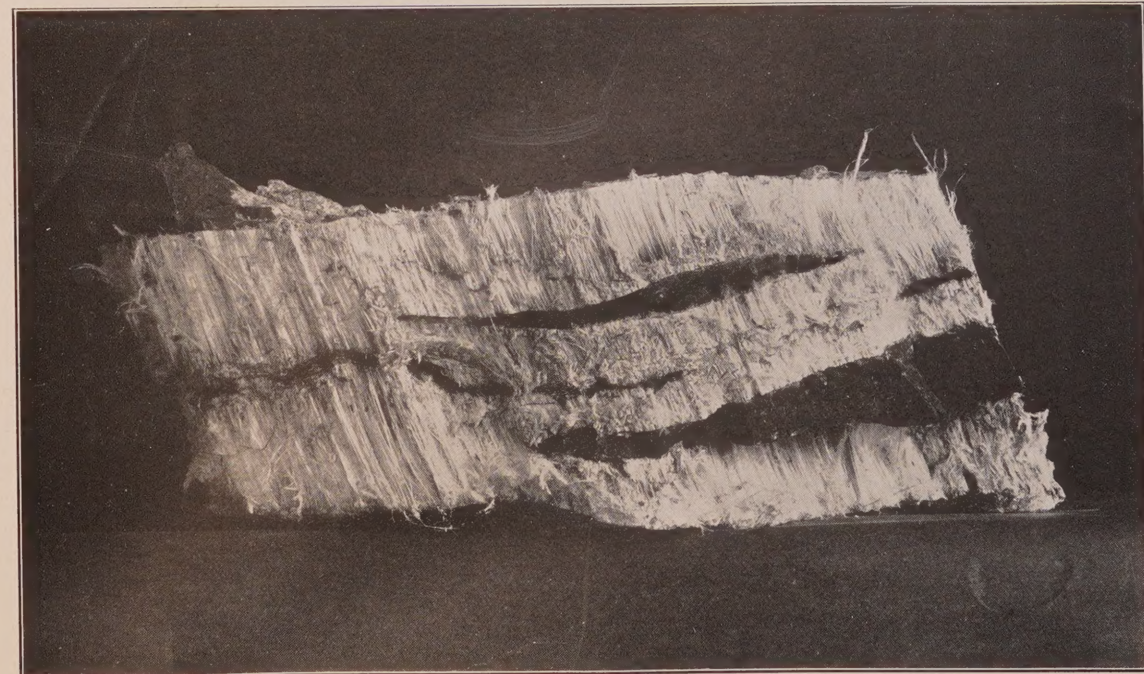
SECOND EDITION
(Enlarged)

OTTAWA
GOVERNMENT PRINTING BUREAU
1910

No. 69

FRONTISPIECE.

PLATE I.



Canadian chrysotile-asbestos, from one of the British Canadian quarries.

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LETTER OF TRANSMITTAL.

To Dr. EUGENE HAANEL,
Director of Mines,
Mines Branch,
Department of Mines,
Ottawa.

SIR,—I beg to submit herewith, a second and enlarged edition of my report on 'Asbestos: Its Occurrence, Exploitation, and Uses'—the first edition of which was issued in 1905. The entire text has been practically re-written, and many new facts and illustrations added. I have to express my indebtedness to the quarry and mill owners, managers and mill-men, and to the makers of machinery used in the manufacture of asbestos products, for their invariable courtesy, and valuable assistance rendered in the gathering of important data utilized in the preparation of this treatise. In addition, permit me to tender to you, Sir, my gratitude for many valuable suggestions, and for kindly criticism of important parts of the manuscript.

I have the honour to be, Sir,
Your obedient servant,
(Signed) **Fritz Cirkel.**

MONTREAL,
January 15, 1910.

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CHRYSOTILE-ASBESTOS

ITS OCCURRENCE, EXPLOITATION, MILLING, AND USES

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Fritz Cirkel, M.E.

INTRODUCTORY.

The asbestos industry of Canada has made phenomenal progress in development and expansion since the winter of 1904-5. This is manifest upon comparing the statistical returns of 1904 with those of 1909. In 1904 the output of asbestos amounted to 35,479 tons, valued at $1,186,795; whereas in 1909 it was 63,349 tons, valued at $2,284,857—an increase in tonnage of 27,870 tons, and in value of $1,098,062. This rapid advance has been primarily due to the discovery of additional deposits, and to the new uses to which asbestos has been applied. As a consequence, new quarries have been opened, new mills established, the annual output largely increased, and the asbestos industry placed on a firmer basis than in any time in its history. Indeed, so great has been the public and commercial interest evoked in this subject, that the first edition of the writer's monograph on 'Asbestos: Its Occurrence, Exploitation, and Uses'—published in 1905—has been completely exhausted, and a new, enlarged, up-to-date edition urgently called for.

In this second edition the writer has endeavoured to give a general account of the asbestos deposits in the Province of Quebec, together with a description of their exploitation—embodying all changes and improvements which have been made during the last five years.

In the method of milling asbestos, very few changes have been made: the general design of the machinery employed being practically the same. In several instances, however, improvements have been made in the installation of separation units, which has largely increased the capacity of the mills; in others there has been a more complete separation of the rock from the delicate asbestos fibre; while in other cases, certain mechanical alterations have produced a higher percentage of the superior class of mill fibre.

Valuable deposits of asbestos have been discovered in the townships of Broughton and Thetford, and added to the productive quarries already in existence; while a number of the older quarries—which, some twenty years ago, were worked for 'crude'—have been re-opened: and several of these gave such promise of remunerative working, that additional mills have been erected thereon.

Owing to the great interest manifested in the possible extent of the serpentine, an effort has been made to delimit the productive area of the serpentine belt of Quebec—which, for over thirty years, has been so extensively exploited. This task was very difficult, owing to the heavy humus which almost universally covers the formation. In many instances shallow openings and pits gave evidence of the existence of productive areas; but the actual extent could not be determined without systematic investigation. Parallel with this inability to make accurate or even approximate deductions as to the extent of known deposits, from the direct evidence afforded by nature, was the equally difficult problem of the determination of depth.

In the examination of magnetic iron ore deposits, for example, the magnitude of the ore body can be approximately determined by magnetometric surveying; but in the case of asbestos, exact science has not yet discovered any method whereby it is possible to forecast the depth of any mine or quarry. This lack of scientific method is largely due to the fact that, asbestos is one of those minerals which, owing to its limited occurrence over the globe, has not been studied profoundly: hence the literature thereon is very meagre, and no method of determining the actual depth of asbestos has ever been published. Perceiving the supreme importance of solving the problem of depth determination, in its varied aspects, a chapter in the following pages has been devoted to the question—'Is asbestos likely to be found at lower depths?' Based upon data gathered in a careful practical study of the asbestos field in the Province of Quebec, the writer has endeavoured to set forth his views on this question: reasoning by analogy as to what relation the known quantities already opened near the surface bear to the still deeper and unexplored parts. And while the writer does not claim that his statement of the case covers the subject as fully as might be expected, yet he conceives that in this way, profitable inquiry and discussion may be stimulated, and that other geologists and mining engineers may be led to express their views also, and thus accelerate the solution of this important problem in the economics of the asbestos industry.

During the course of the above-mentioned studies, the writer was enabled to gather important data which not only throw additional light on the obscure origin of asbestos, but go far towards explaining its geological formation. These research data, together with a condensed account of the asbestos deposits in the Province of Quebec; a description of their exploitation, and a record of the changes and improvements made during the last five years, should render this treatise useful both as a text book and as a work of reference. Almost every page has been re-written, except the descriptions of existing machinery. In the preparation of the chapter dealing with the practical uses to which asbestos is being applied, special care has been taken to present only such information as came direct from manufacturers, and persons whose veracity could be relied upon.

A new feature, not only of academic but of technical interest, is the reproduction of a number of microphotographs and drawings, showing the fibre structure, etc., of chrysotile-asbestos in its varied forms; while the photo-en-

gravings of deposits, quarries, plants, etc., are all new: taken either by the author, or by a reliable, local photographer.

One word more. In many technical publications the term 'asbestos mines' is used. This is a terminological error; since these so-called 'mines,' are only open quarries, similar to ordinary stone quarries, as the various photographic views interspersed throughout the text will show. In this second edition, therefore, 'quarry' is applied instead of 'mine.'

CHAPTER I.

HISTORY, AND PHYSICAL AND CHEMICAL PROPERTIES OF ASBESTOS.

Historical.

The use of asbestos can be traced back to ancient times. The Romans drew their supplies from the Italian Alps, and even from the Ural. They imagined it to be of vegetable origin: the highly silky appearance and unctuous feel giving them the impression that it was an organic substance.

It is said that cremation cloth, in which dead bodies were enwrapped to be consumed by fire, was made of asbestos. It appears, however, that the high cost of making this asbestos cloth militated against its general use. Pliny refers to it as a rare and costly cloth—'linum vivum[1]—'the funeral dress of kings' he calls it: evidently assuming that it was of vegetable origin. The fibre used came from the Italian Alps and was called 'amianthus.' It was apparently very difficult to spin, on account of its shortness; but judging from a piece of asbestos cloth on exhibition in the Vatican, and which is said to have originated in the days of ancient Rome, it is certain that vegetable fibre was intermixed with the real asbestos fibre in the making of so-called asbestos cloths. There is, moreover, according to Sir E. J. Smith, in the library of the Vatican, a winding sheet of Italian asbestos, which, although very coarsely made, is of a very soft and silky texture. This piece of cloth—perfectly preserved—was, together with some ashes, found in a sarcophagus in the Via Praenestina in 1702. It was subsequently placed in the Vatican Library by order of Clement XI. It appears that some vegetable fibre was used with real asbestos fibre in the making of the cloth; because it is reported that, when fire was applied at one end of the cloth, it burned with brightness, but leaving the real mineral fibre intact.

When Marco Polo was travelling in the thirteenth century through Siberia—at that time known as the Great Empire of Tartary—he was shown some cloth that withstood the action of fire. Marco found that it was made of a fibrous mineral called 'amianthus,' which resembled the Italian asbestos. Upon further investigation he found that, the ore from which this fibre was extracted, was first dried, then pounded in a mortar, and after the impurities had been eliminated, the pure silky fibre left was used in a spinning process, the *modus operandi* of which is unknown. The fibre referred to in Marco Polo's travels, was long, beautifully white, and silky; and probably belonged to the variety known to-day as 'hornblende asbestos.' This same variety is found in Corsica. Before its real value became known, it was used as a packing tow, and Dana reports that Dolomiea when packing up minerals for his collection on that island, used it in tying the boxes.

[1] Quenstedt, Handbuch der Mineralogie.

That asbestos was used in ancient times as lamp wicks is recorded by Plutarch, who called them 'perpetual'; for the reason that the wicks never seemed to wear out. These lamps were principally used by the Vestal Virgins. The wicks, made of delicate asbestos fibre, formed small tubes through which the oil passed, while the wick itself remained intact. Pausanian mentions a lamp that was filled with oil only once a year; he evidently attributes to the oil what should have been credited to the wick—which was not consumed at all. He notes that the wick was made of 'Carpasian' linen, referring to a mineral fibre obtained from Carpasius in Cyprus. It is said that Kirchner the German philosopher used in his library a lamp which had a wick made of 'amianthus.' Whatever the uses of asbestos may have been in days of old, it is certain that its peculiar non-combustible and spinning qualities were recognized and taken advantage of from the first; but it remained for modern times to make the mineral of commercial utility and an important factor in the industrial market of the world.

Although the discovery of this mineral is attributed to the Romans, who, as already related, mined it in a small way in the Alps, the knowledge of its existence—which may not have been more than local—apparently lapsed. Only in a few instances is it mentioned, or its utilization referred to in the literature of the middle ages. It appears that in the year 1720, asbestos was discovered in the Ural mountains; and forty years later—under the reign of Peter I—a factory for the manufacture of asbestos articles was established near the Naviansky works. But the known uses were so few, and the demand so limited, that the industry subsequently disappeared; and it was not until some forty years ago that technical interest in the mineral was revived in Europe. In the domain of applied mechanics its non-combustible properties were no sooner realized, than investigation of its nature and utility was begun in earnest —with a view to its application on a commercial scale. Since 1860, the search for asbestos has been incessant; the exploitation and development of the deposits discovered remarkable; and the progress made in the invention of mechanical methods for refining and preparing the mineral for utilization in the industrial world simply marvellous.

The first modern attempt to exploit asbestos deposits was made in the Aosta valley of the Italian Alps by a London syndicate, for the purpose of experimenting on a large scale; and almost simultaneously with the exploitation in Italy asbestos was discovered in the Des Plantes River region, between St. Joseph and St. Francis villages, Province of Quebec. At the exhibition in London, in 1862, a specimen of fine, silky-fibred asbestos from the above locality was exhibited.

The extension of the belt of serpentine rocks in which the mineral was known to occur had been traced with some care from the Vermont boundary in the township of Potton, to, and beyond the Chaudière river; but the deposits of asbestos discovered were comparatively limited. All attempts to work them profitably failed, and during the next fifteen years nothing was done in the way of exploration or exploitation.

In 1877, however, asbestos was found in another district in Quebec; this time in the serpentine hills of Thetford and Coleraine. The credit of this dis-

covery is claimed by Mr. Robert Ward; although by others it is stated that the first find was made by a French Canadian named Fecteau. Following closely upon this discovery several parties secured areas both at Thetford and Black Lake in Coleraine township, close to the line of the Quebec Central railway, which, for some miles, runs through a belt of serpentine. Large fires having swept over the country, destroying all forests, the discovery of veins was facilitated by the weathering of the mineral on the surface.

Mining operations on a small scale commenced in 1878, and in this year fifty tons were produced; but it was difficult to find a market. The quality of the fibre mined was excellent, and the width of the veins everything that could be desired: being from ½″ up to 2″, 3″, and sometimes 4″. This justified the expectation that large deposits of the mineral might exist in that locality, though their true importance and value were not ascertained for several years later. Shipments of the better grades to London created quite a sensation in the British market; hence extensive tests and investigations were made, with the result that, on account of its exceptional spinning qualities, high prices were soon established, and the race for the acquisition of additional areas likely to contain the valuable mineral began. The land upon which the asbestos was found was considered of very little practical value, either for agricultural or any other purposes, and mining operations were rapidly extended. The principal areas in which the asbestos-bearing serpentine was found to occur were lots 26, 27, and 28, near the line between ranges V and VI of Thetford, and in the township of Coleraine near Black Lake station, four miles southwest of Thetford station, in an area previously unsurveyed; but adjoining, on the southwest, range B, also on lots 27 and 28, range B; and on lot 32, range C. All these areas were speedily secured, as well as most of the serpentine-bearing ground extending southeastward from the Quebec Central railway towards Caribou lake, and for several miles along the Poudrier road.

During the next twelve years a rapid development of the asbestos industry was witnessed. The mines were operated on a large scale; while prospectors were busy exploring the hills of the surrounding country for new deposits of the mineral. Villages sprang up in the vicinity of the mines as if by magic, although the country—physically speaking—was sterile and very rough. Prior to the beginning of mining operations, the population consisted of only a few scattered families, but now increased to several thousands, and the whole country showed all the marks of industrial activity and prosperity.

In 1885, it was reported that seven quarries were in operation, which produced during the same season an aggregate of about 1,400 tons of asbestos. The prices obtained for the different grades were: first quality, $80 per ton at the mines; second quality, $60; third quality, $40, and the lower grade—suitable only for pulp—$10. The total number of men employed by the various operating companies was 350; distributed as follows: King Bros., 40; Boston Asbestos Packing Company, 100; the Johnson Company, 100; Ward Bros., 20; Lionais & Company, 40, and Irwin & Hopper, 50.

Dating from 1885, a gradual increase in the prices took place: especially for the first and second qualities. In 1900, about $300 was realized for the first

First asbestos mill, erected and designed by Earle C. Bacon, C.E., New York, at Black Lake, in 1888, on property now owned by the Amalgamated Asbestos Corporation.

quality. This, and other economic features in connexion with the industry, served to give a powerful impetus to the development of the existing asbestos resources: additional mines were opened; the demand for the mineral continued brisk for a time; and properties were sold at a high figure. At a meeting of the Bell Asbestos Co., Limited, held January 30, 1889, at the Cannon Street Hotel, London, England, the Chairman—Mr. John Bell, announced a dividend of 22½ per cent on the capital stock of the Company for the year 1888, and said that the large growth of the asbestos business in general promised even better prospects for the current year.

But this state of affairs did not continue long; prices began to drop gradually, the demand slackened, and it was discovered that the prevailing methods of hand extraction were faulty, inadequate, and expensive: especially with regard to the lower grades. As a matter of fact, under prevailing price conditions, only those quarries which were working on rich ground, and had a large percentage of crude asbestos, had a chance to live, and carry on operations with a profit. The natural outcome of these adverse conditions was obvious: many quarries producing only a very small percentage of the higher grades were forced to shut down; and this, together with serious difficulties accentuated by overproduction and a consequent fall in prices, caused the industry to receive a severe set back in the middle of the nineties. For some years the industry languished, and this had a depressing effect on all except those who would not be discouraged, or who were naturally optimistic.

Those engaged in the quarries and those having the development of the industry at heart perceived that only one thing could save the industry, namely, a more economic production; hence they began to exercise their inventive powers; the result being that, mechanical treatment of the lower grades of asbestos gradually displaced hand-cobbing: and this method, in the course of years, was applied with such conspicuous success that, to-day, every quarry in the district is equipped with a complete milling and fiberizing plant. By means of this improved process, all the smaller fibre—which in the earlier years was left in the rock and thrown into the dump—was saved; and as new demands for this short material sprang up, the life of a quarry was prolonged, and its operations performed with greater ease and economy.

As a result of these innovations, fifteen quarries and nineteen mills, with a capacity of 8,520 tons of asbestos rock per day, are operating at the present time in the Province of Quebec; and it is confidently predicted, that the capacity of the quarries and mills will be largely increased during the course of the year 1910. The flourishing condition of the asbestos industry is a striking example of what human ingenuity can accomplish when applied in the right direction.

The quarrying and production of asbestos in the Eastern Townships of Quebec, is, to-day, one of the most prosperous industries in the Dominion of Canada. Previous to the discovery of this mineral, the district was but sparsely populated—being in a like condition to the famous Cobalt region prior to the discovery of silver—but continued success in exploitation and development has attracted thither a large mining and trading class, hence the population has

two companies operating in the district: the 'International Asbestos Company' with head offices in New York, and the 'Joseph James Company' of Actinolite. It is claimed that from 30 per cent to 40 per cent of all the rock mined went through the mill, and that of this about 10 per cent was extracted as fibre.

Actinolite is also found in some of the hornblende rocks of the Sudbury district, where the writer found fibre measuring from 6 to 10 inches long. The market for this mineral is, however, very limited; and the prices are, as a rule, not satisfactory. For this reason, mining is carried on spasmodically, and even then on a very limited scale.

The following analyses of samples of hornblende minerals from different localities[1] will illustrate the chemical percentage of the composition:—

—	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	H_2O	F_2	XyO*	Total.
I	57·5	1·3	0·2	0·2	24·9	12·8	0·7	1·3	·9·8	0·6	100·3
II	56·1	1·2	9·8	5·5	21·2	12·1	0·2	1·9	0·1	0·6	99·7
III.	41·9	11·7	2·5	14·3	11·2	11·5	2·7	0·7	0·8	2·6	99·9
IV	43·8	4·4	3·8	33·4	0·8	4·6	8·1	0·1	....	1·5	100·5
V	55·6	15·1	3·1	6·8	7·8	2·4	9·3	....	....	9·5	100·6

* Small quantities of minor components.
I Tremolite, Richville, Gouverneur, New York.
II Actinolite, Greiner, Tyrol.
III Hornblende, Edenville, Orange county, New York.
IV Arfvedsonite, Kangerdluarsuk, Greenland.
V Claucophane, Island of Syra, Greece.

Asbestos.—Tremolite, actinolite, and other varieties of amphibole—excepting those containing much alumina—pass into fibrous varieties, the fibres of which are sometimes several inches long: fine, flexible, easily separable by the fingers, and looking like flax. These varieties are called 'asbestos,' 'hornblende asbestos,' or 'amphibole asbestos.' They usually exhibit a dull green colour, have a somewhat unctuous feel, and display occasionally a pearly lustre. They are closely allied with the pyroxene and hornblende rocks, and the name 'asbestos' is to-day only applied to these varieties; while the true silky kind—which forms the basis of extensive mining operations in Canada, is called chrysotile.

The Italian asbestos is asbestos properly so-called; for it consists of the highly fibrous form of hornblende, hydrated, and is mineralogically distinct, and entirely different, both in form and appearance, from the Canadian chrysotile. Notwithstanding the totally different physical character of the two, as found in the rock, in chemical composition they are very similar, and in many of the uses to which both minerals are put, they are treated as identical. When mechanically prepared, however, the Canadian chrysotile looks so much like real 'asbestos' that both are often sold one for the other. Further particulars regarding Italian asbestos will be found on page 230 under 'Italy.'

Mountain Leather and Mountain Cork.—(Bergfleisch, Bergleder).—Mountain leather occurs in thin flexible sheets made of interlaced fibres; mountain cork is the same, only in thicker pieces. These varieties contain little or no

[1] "Rocks and Rock Minerals" Pirsson. Page 64.

Italian (hornblende) asbestos.

alumina; they do not readily separate into fibres; and are unsuitable for most of the purposes for which asbestos is generally used. The 'cork' variety, which possesses the elasticity and lightness of cork, is usually of a light brown colour, and has a specific gravity of 0·68 to 0·99. The water in both mountain leather and cork is occasionally from 2 to 3 per cent, and sometimes more. According to Quenstedt, the composition of mountain cork is:—

Silica	57·20
Peroxide of iron	4·37
Magnesia	22·85
Lime	13·39
Water	2·43
	100·24

Mountain Wood. (Bergholz, Holzasbest, ligniform asbestos).—Mountain wood is compact, fibrous, and grey to brown in colour, looking somewhat like dry wood, also like petrified wood; in fact it might be readily mistaken for it, especially when sufficient oxide of iron is present to impart to it the tawny tinge of decayed wood or bark. The crystal fibres, however, are readily recognizable under the microscope: the absence of vegetable cells—which are always present in petrified wood—being clearly noted. Moreover, they are generally long, from a few inches up to 1 or 2 feet, and are curved and compact, but varying much in texture. This mountain wood is occasionally found in the Canadian asbestos deposits: some of the specimens obtained resembling the choppings of wood, and hardly distinguishable from the latter, except by handling.

Crocidolite: Blue Asbestos (Blauer Asbest).—This variety is found in Griqualand, South Africa. It is a beautiful mineral, of a highly fibrous texture, the fibres being easily separable by the fingers. Its specific gravity is 3·20 to 3·30; its lustre very silky, and of a dull, lavender blue colour due to the presence of ferrous oxide. The fibres are quite elastic, and are, occasionally, several inches long. Its chemical composition is $Na\ Fe\ (SiO_3)_2,\ Fe\ SiO_3$. Theoretically it contains:—

Silica	49·6
Iron sesquioxide	22·00
Iron protoxide	19·80
Soda	8·60
	100·00

As compared with 'chrysotile,' it possesses remarkable tensile strength; but it is different in fire resisting qualities, and for that reason its substitution for chrysotile—which was at one time attempted—was a complete failure. While good asbestos fibre contains almost 80 per cent silicate of magnesia, and only from 1 to 3 per cent oxide of iron; crocidolite contains only 50 per cent silica, and not less than from 34 to 48 per cent oxide of iron. A number of experiments were made with crocidolite several years ago, by Mr. Alfred Fischer. General Manager of the United Asbestos Company, 'Limited,' London, with a view to utilizing the African fibre; but the results were very unsatisfactory; and

it was stated at the time that, the fibre was unsuitable for engineering purposes, since it would not stand much heat withot disintegrating and becoming quite rotten, this negative result being probably due to the fact that, a portion of the iron disclosed by analysis was in the form of a ferrous salt. It is further stated that when exposed to the air and heat, this salt oxidizes, and alters the composition of the asbestos to such an extent that it is easily charred.

Haussman[1] states that a cylinder made of crocidolite 4/100 inch in diameter supported 91 Hanoverian pounds without breaking; whereas one made of asbestos 7/100 inch in diameter broke with a weight of 6 ounces. (No mention is made, however, of the kind of asbestos employed in this test). It is probable that this remarkable tensile strength is due to the large amount of iron in its composition; but as noted before, it does not possess the fire resisting qualities which are so essential in the commercial asbestos fibre, owing to the absence of magnesia. In the following table two analyses are given of this mineral: No. I is mentioned by R. Jones, in his treatise on 'Asbestos,' page 25; while No. II is from De Larrarent[2]:—

	No. I.	No. II.
Silica	51·1	51·22
Protoxide of iron	35·8	34·08
Soda	6·9	7·07
Magnesia	2·3	2·48
Oxide of manganese	..	0·10
Lime	..	0·03
Water	3·9	4·50
	100·0	99·48

Some of the South African asbestos is largely altered by both oxidation of the iron present and infiltration of silica; resulting in a compact siliceous stone of delicate fibrous structure 'chatoyant' lustre, and bright yellow to brown colour, popularly called 'cat's eye,' (Katzenauge, German). A similar lustre is found in a calcedonic quartz: this mineral, when freshly cut, sometimes exhibits opalescence, and glaral internal reflection. Further particulars on this mineral will be found on pages 240 and 241, under the heading of 'Africa.'

Crocidolite has lately been found in the Pilbarra district, Western Australia, by Mr. Herbert Soanes, of Perth. This mineral resembles very much the South African variety: is of a lavender blue colour, and occurs in a brown, ironstone shale. Mr. Soanes reports that, although some surface samples are exceedingly brittle, he has seen specimens from unusual depth, which are very silky and of remarkable tensile strength.

SERPENTINE.

Serpentine[3] has been rightly called 'the mother rock of the regular silky asbestos fibre.' Comparing the really beautiful fibre which is produced from the Canadian quarries—more especially those at Thetford—with a large number of

[1] Haussman, Handbuch, 1847. Page 734.
[2] Cours de Mines. 84.
[3] The name 'Serpentine' alludes to the green serpent-like cloudings of the serpentine marble.

specimens from all parts of the world, the author is of opinion that, as far as useful, high-grade, commercial qualities are concerned, there is only one country where this fibre is to be found at the present time, namely, Canada. Asbestos fibre has been found in almost every quarter of the globe: Newfoundland, the United States, Italy, South and Central America, China, Japan, Australia, Spain, Portugal, Hungary, Cyprus, Germany, Russia, Siberia, the Cape and Central Africa; and scarcely a month passes without an announcement in some technical journal of the discovery of a new asbestos field. But nearly all the discoveries made up to the present time—except perhaps those in the Ural mountains, Russia—are, from a commercial standpoint, of very little value; for 85 per cent of the asbestos supplied to the world's market is produced in Canada.

The Canadian serpentine has three, distinct fibrous forms:—

(1) Picrolite.

(2) Soapstone (talc).

(3) Chrysotile.

Although picrolite and chrysotile—the two offsprings of serpentine—are similar in chemical composition, their difference in external appearance and physical qualities generally is so great, that at first sight their common identity in the same group of minerals seems doubtful; indeed among all the rocks of igneous origin there are none that so much puzzle the petrologist in his attempts at a rational classification, as the small group representing the serpentine. In some localities in eastern Canada serpentine rocks exist in considerable magnitude. Mineralogically, it is a hydrated silicate of magnesia, resulting from the alteration of magnesian rocks, is infusible, and, as a rock proper, without crystallization; chemically, its constituent formula is $3MgO$, $2SiO_2$, $2H_2O$—silica 44·1, magnesia 43·00, and water 12·9=100. It occurs, generally, in the crystalline series, with eruptives, etc., and the common assumption is, that it is derived from olivine or peridotites, because it sometimes exhibits the characteristic form of crystals of peridotite, the essential constituent of which is olivine. Serpentine may, therefore, be classed as a hydrated peridotite or olivine. In the latter, under the action of carbonated waters, the iron is frequently carried off, instead of being peroxidized; some of the magnesia being removed at the same time. The resulting rock is serpentine, which, in some noted localities, remains for the greater part as a rock-mass, and in fibrous varieties. Olivine is often full of fissures, and it is in these fissures that its transformation into serpentine commences. Under the microscope it appears as a finely fibrous, green fringe; the fibres lying at right angles to the surfaces from which they originate. Then, as the alteration proceeds, this fibrous structure seems to extend farther inwards, until the whole is converted into a mass of interlacing, contorted fibres. When crystals of olivine are only partially altered, they appear in disconnected fragments, the spaces or interstices between these fragments being occupied by fibrous serpentine, which represents the incipient decomposition of the olivine along the irregular cracks which traverse the mineral so frequently.

The hardness of serpentine is from 3 to 3½, and its specific gravity 2·5 to 2·7. As a rule, serpentine is found in massive form; but it occurs also as a banded, schistose, and slaty structure. Its colour is from a very dark-blackish

to a light green; sometimes brown-red on decomposition surfaces. The lustre is subresinous to greasy, pearly and waxlike, seldom earthy. On smooth surfaces the rock has a somewhat greasy feel, suggesting talc; but it can readily be distinguished from the latter by its hardness. The yellow-green colour resembles that of epidote rocks, but here also the greater hardness of the latter serves as a distinction.

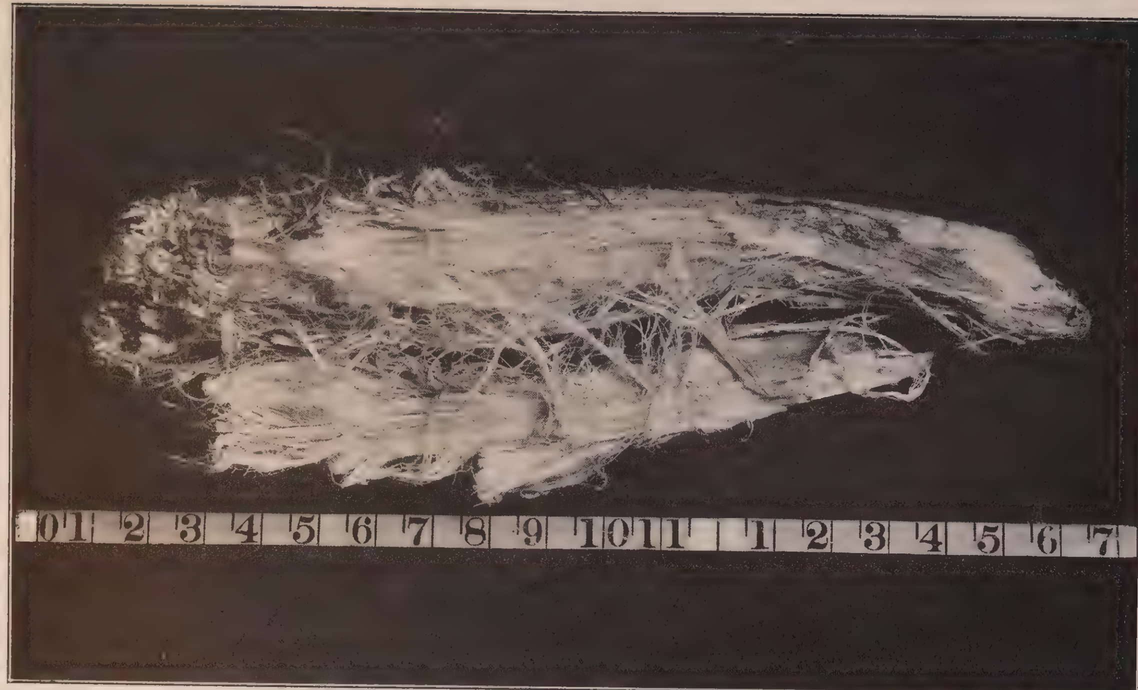
Other minerals which occasionally accompany the serpentine are remains of the magnesia silicates from which it has been formed. Olivine and chrome iron ore, either in grains or in pockety accumulations, are frequent constituents of serpentine. In the Eastern Townships of Canada, it forms in some localities the objective of extensive mining operations, notably to the south of Black Lake. Minute grains of the same material are found in close association with asbestos fibre; it may be seen in fine stringers $\frac{1}{16}''$ thick, accompanying the asbestos veins, either in the rock parting, generally dividing an asbestos vein in the middle, or accompanying the same on the outside in the solid serpentine rock. It may be noted, however, that at the present time no occurrence is known in the district where the two minerals—chrome iron ore and asbestos—are mined together: to use the miners language, they cannot 'live' together.

The harder varieties of serpentine show great resistance at the surface to the action of weathering agencies: but eventually they yield to these influences, like the softer serpentine, and decompose. The resulting product shows a loss in silicate and magnesia, on the one hand, with enrichment in alumina, volatile matter, and principally iron on the other. An analysis of a decomposed, brownish serpentine, taken from a surface outcrop, gave the following percentage composition:—

SiO_2	34·70
Al_2O_3	2·95
Fe_2O_3	6·50
FeO	4·20
MgO	32·10
Moisture	3·96
Loss in ignition	21·03
Total iron expressed as:—	
Fe_2O_3	11·17
FeO	10·05

The soils formed from this decomposed material are, on account of the lack of alkalis, extremely barren, and are devoid of any vegetative power.

The writer has occasionally espied a mineral which is frequently found associated with asbestos veins—accompanying the latter as small stringers $\frac{1}{8}''$ to $\frac{1}{4}''$ wide. This was first designated in the field as a cherty 'hornblende,' but on close examination it turns out to be an 'opaline serpentine.' This variety is light green in colour, with a fading, yellowish tinge; it is a little harder than ordinary serpentine, resembles in appearance the paler varieties of 'Colorado turquoise'; and, in the opinion of the writer, would make an excellent gem. It was found in the lower pit of the Megantic mine (of the late Asbestos Mining and Manufacturing Company), also in an asbestos deposit close to Mansonville, Que., twenty-two miles south of Eastman.



Picrolite.

Owing to the brilliant colouring effects of serpentine, efforts have been made to utilize it in ornamental work for indoor decoration: mantle-pieces and statuary have been produced therefrom, showing beautiful effects; and it would be more extensively used for decorative purposes were it not for the fact that, the rock is easily disintegrated under the influence of atmospheric agencies. In the 'Perkins Mills' district (fifteen miles northeast of Ottawa), where mining for asbestos was carried on during the years 1891-1893 (see pages 36-41) efforts were made to utilize the highly coloured serpentine for ornamental work, and the 'Canadian Granite Company,' of Ottawa, quarried serpentine for some considerable time, and worked it in their factory; but it was found that the many joints and seams interfered seriously in the dressing, and it was difficult to secure good solid pieces for polished work. In the Thetford district, like difficulties were experienced. Comparatively large blocks were obtained in some of the quarries; but owing to the numerous joints and fissures therein, the decorative results achieved were very unsatisfactory. Recently, serpentine has been quarried in Vermont, U.S.A., and sold under the name of 'Verde antique marble.'

Picrolite.—(Pikrit), is one of the principal fibrous varieties of serpentine. It resembles coarse asbestos, and occurs in fibrous aggregations in fissures or long slickensides (polished rock surfaces originated through rock movements), of the serpentine. It is found in almost every asbestos mine in Canada, and is called by the miners 'bastard asbestos.' Owing to the difficulty in distinguishing this material from asbestos proper, it finds its way, to some extent, into the mills, where it is fiberized with the asbestos. Its specific gravity is 2·607. The fibres are sometimes 8″, 10″, and 12″ long, but are not easily flexible. They are, as a general rule, harsh to the touch, sometimes brittle, not easily separable, and often exhibit a splintery fracture. The colour is dark and light green, sometimes grey and white. Picrolite is not, at the present time, used in commerce, nor in the arts; but judging from the similarity in chemical composition, as well as from its physical properties, to asbestos—as such, there seems to exist a good reason for the belief that some day this mineral will be utilized: either in its natural state, or after pulverization, cleaning, and refining. An analysis of picrolite from East Broughton and Bolton gave the following results:—

—	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	H_2O	Authority.
East Broughton.....	37·88	1·10	2·70	0·36	0·82	43·29	14·52	Dr. Milton Hersey, Montreal.
Bolton	43·70	....	3·51	....	....	40·68	12·45	Dr. J. T. Donald, Montreal.

Soapstone (Steatite).—(The massive form of 'talc'). This mineral is frequently found associated with serpentine, especially in Broughton township in the westerly part of Thetford; at Lake Nicolet in the townships of Wolfestown, Sutton; and in Potton, Province of Quebec; also in Elzevir, Hastings

county, Ont. It occurs in very irregular deposits, which sometimes take the shape of bands, lenticular masses, and so-called 'stocks;' having a width of from 1 or 2 feet up to 20 or 30 feet, and even larger. Frequently, asbestos veins are abruptly cut off by the intersection of a soapstone deposit; but generally, they are again found on the opposite side of the latter. Soapstone is an alteration product of magnesian minerals—especially serpentine; and in several localities in the Eastern Townships is almost exclusively associated with the latter. In some places it shows transitions into other rocks, such as chlorite schist, crystalline dolomite, quartzite, etc. It occurs in massive form, but has sometimes a pronounced schistose cleavage and character. Other minerals also occur in different varieties of the rock, such as quartz and calcite in grain lenses and veins; chromite and magnetite in black spots; hornblende in green prisms; also chlorite. Soapstone is soft: the hardness being 1 to 1·5 Mohs scale; and specific gravity 2·75. Its colour is apple-green to white, greenish grey, and dark green; sometimes bright green perpendicular to cleavage surfaces. When impure its colour is dark green and blackish blue. Soapstone has a greasy feel and has often a pearly or tallowy appearance on the cleavage surface. Its infusibility before the blow-pipe, and its insolubility in acids distinguishes it from similar looking minerals. When intensely heated in a closed tube, most varieties yield water. When moistened with cobalt solution, it assumes on ignition a pale red colour. The rock cleavage is often thinly fissile, sometimes thicker, and oftentimes the cleavage is entirely wanting; it is then nearly massive, compact, and has a wax-like aspect.

The commercial value of talc and soapstone depends chiefly upon their purity, also to some extent upon their colour (white), and upon their soapy touch—when ground very fine. The market requires a plaster or air separated mineral, free from grit, quartz, mica, etc. Soapstone possesses a variety of qualities which render it adaptable for many uses. It is not liable to corrosion; withstands expansion or contraction in different ordinary temperatures; and is unaffected by moisture, or chemical fumes. When pure it may be sawn into slabs, or manufactured into pots and other vessels. It is utilized, at present, in the manufacture of gas jets, table tops, sinks, etc., and other interior fittings, where its non-corrosive qualities render it valuable. Owing to its refractory character, it is admirably adapted for use as firestones, and as lining for furnaces and fireplaces. When exposed to high temperature it loses its small portion of water, and then becoming much harder assumes a dark green colour and is susceptible of a fine polish. In the last-named condition it is used for the manufacture of images: chiefly by the Chinese and Japanese.

It possesses great power of resisting atmospheric influences, and chemical action. It is used as a preservative of wood-work, and often, in powdered form, is put on buildings and monuments to save the surfaces from disintegration. Utilized in this way, it has the property of clinging to metal and stonework with the tenacity of gold leaf. For hundreds of years it has thus been used in China and Japan, with remarkable success.

The use of powdered soapstone in paint is well known. By using a suitable varnish in connexion with powdered soapstone, both sea water and the atmos-

phere are prevented from coming into direct contact with the steel of ships; rendering their hulls perfectly air and water-tight. This paint, if properly prepared, will not crack with the vibration of the vessel, nor by the contraction or expansion of the steel. Varnish, used alone, is porous, and admits the atmosphere and moisture to the body coated with it; but when mixed with powdered soapstone—owing to the infinitesimal, fine division of the mineral the pores are completely closed, and are thus shut off from the influence of air and water.

It is, moreover, used as a filler for paper, electric insulators, foundry facings, waterproof wall plaster in bathrooms, ornamental finishing on walls, shoe powder, waxing floors, dressings, tailors' chalk and crayons, firebrick, laundry, bath, and chemical tubs, hearthstones, mantels, slate pencils, and griddles. Talc of a dark colour is used as an adulterant of graphite for lubrication. It is used for switchboards; since it is not only hard enough to take a polish, but the ease with which the numerous holes required in all switch and keyboards can be drilled, renders it a very desirable article for this electrical work.

The ground article is also used in pigments, cosmetics, face and tooth powders, lubricants, skin and leather dressings, and as an adulterant for soap.

It is surprising that soapstone is not more extensively used in heating stoves. The typical German porcelain stove, used so largely in Bavaria, is composed of pieces of porcelain, which do not become abnormally hot, but have a great capacity for retaining heat. If the fire is raised to a moderately high temperature, they cool slowly, and give out a gentle heat for some hours: thus a room 16 feet square by 8 to 9 feet high, is made, even in mid-winter, quite comfortable for a whole day by one or two small fires. Stoves made out of soapstone might be made ornamental in design, and when sufficiently thick, would retain their heat like the 'Berlin' stove, effecting a great saving in fuel and labour.

During the last few years the use, in Europe, of soapstone or talc as a filling material in the manufacture of paper and for producing smooth, silk-surfaced paper, has considerably increased. Although the price of soapstone is higher than that of kaolin—which is employed for the same purposes—its application is more desirable where a higher grade of paper with a better finish is required. It is claimed that the surface produced by soapstone, compared with that of kaolin, is far superior. It effectively absorbs both printing and writing inks. The use of the mineral gives strength, weight, and durability. For certain common kinds of wall paper, pulverized mica is used to produce a glossy effect.

Soapstone deposits are found in many parts of the world. In the United States it can be mined in large quantities, remarkably pure in quality. In California rich deposits have been found in several districts; while in Arkansas a fine quality occurs in Saline county. In the last-named regions the deposits are closely associated with slates and serpentine; but in the aggregate they are very pure, containing about 62 per cent silica, and 34 per cent magnesia.

In Canada, deposits excellent in quality (the foliated species 'talc') are found in Hastings county, Ontario, not far from the town of Madoc; while a considerable quantity of soapstone, in a comparatively pure condition, exists in

Thetford and Broughton townships, eastern Quebec. In these latter places the surface outcrops have a rusty appearance; often resembling in this respect the outcrops of some qualities of serpentine: with this difference, however, that it is much softer than the latter. These rusty surface outcrops constitute the decomposition product of the original rock, the silica having been leached out to some extent, with corresponding enrichment in magnesia and carbonates.

The soapstone deposits of the Eastern Townships have not commanded that attention of capitalists which their quality would warrant. The writer has seen in that region some excellent deposits, of a quality which, in his opinion, outrivals the product from many of the principal talc and soapstone centres of the United States. Slabs, and variously formed objects have been sawn out of 'Thetford' soapstone, and the articles produced were found amenable to all sorts of handling and working. Switchboards and keyboards can be made out of the material, as holes for screws, etc., can be drilled therein with ease.

Chemically, soapstone consists of silica and magnesia, with certain oxides, and a small amount of water. Analyses of four samples of soapstone from Broughton gave:—

ANALYSES OF SOAPSTONE, BROUGHTON, QUE.

Constituents and Chemical Formulæ.	Authorities.			
	Sample A. — H. Verger, Paris.	Sample B. — H. Verger, Paris.	Sample C. — Prof. McCandles Jones (from '*Asbestos*').	Sample D. — Dr. Milton Hersey, Montreal.
Moisture	0 30	3·60	0·48	2 64
Chemically bound water	3·95			
SiO_2	61 50	62·80	63·70	56·20
Fe_2O_3	0·11	0·25		
FeO	.....	.....	1·46	
Al_2O_3	0·89	0·20	0·42	
MgO	33·03	33·10	33·75	32·65
CaO	0·16	.....	.....	
Loss	.....	.....	0·19	
	99·94	99·95	100·00	

Analyses of the foreign varieties of talc and soapstone are given in the following table[1]:—

ANALYSES OF FOREIGN TALC AND SOAPSTONE.

Countries.	SiO_2	MgO	FeO	CaO	H_2O, CO_2 etc.	Al_2O_3	Na_2O, K_2O
Austrian	59·59	32·92	0·79	0·59	3·79	1·76	0·56
French	50·91	24·86	2·58	1·82	6·64	13·19	
Italian	51·23	33·32	1·89	1·80	5·46	7·08	0·22

[1] 'Min. Industry,' 1897, page 634.

Soapstone is sometimes found in fine granular or cryptocrystalline form, milk-white in colour, and of pearly lustre. In this condition it is often used as 'French chalk' by tailors for marking cloth, removing grease, and other stains. The following are two partial analyses of this variety:—

ANALYSIS OF 'FRENCH CHALK.'[1]

SiO_2	62·80	63·49
MgO	33·50	31·75
H_2O	3·70	4·76
	100·00	100·00

Chrysotile.—The next, and most important fibrous form of serpentine is 'chrysotile'—or, as it is generally called, 'asbestos.' Previous to the general application of chrysotile-asbestos, the beautiful, white, flexible fibres in use were distinguished by the Roman name of 'Amianthus,' in contra-distinction to the brittle and less silky varieties. 'Amianthus' is found in the older crystalline rocks: in the Pyrenees, on Mount St. Gothard; in the Ural mountains, and in New South Wales. This name, however, is applied to-day to all fine qualities of asbestos and chrysotile alike. Dana refers to the mineral thus: 'amianthus includes the fine silky varieties, much so-called in serpentine which is hydrous and therefore easily distinguished.'

Physical Properties.—Sterry Hunt[2] says: 'Chrysotile constitutes the common 'Amianthus' and has hitherto been regarded as a variety of serpentine, with which it agrees in centesimal composition. It is, however, distinguished from it by a lower specific gravity, and by its fibrous character, which like that of amianthoide amphibole, indicates a prismatic crystallization.'

To be of any commercial value, asbestos needs length, fineness of fibre, combined with infusibility, toughness or tensile strength, and flexibility. It is surprising that sometimes specimens from foreign countries—although very beautiful in appearance—are often wanting in some of these essential physical properties. Qualities like silkiness, length, and flexibility may be determined very easily by the eye and fingers; but tensile strength, and infusibility—those necessary qualities upon which the great value of asbestos depends—can only be determined by systematic tests, made either in a practical way during the course of manufacture or in the laboratory. The Canadian chrysotile-asbestos possesses all the above-mentioned properties and qualities in a marked degree: the length of the fibre being one of the principal factors determining the different grades. The main difference between asbestos and any other material or substance is its finely fibrous structure; and it may be said that these beautiful fibres—resembling fine, silk-like threads—may be termed 'a mineralogical phenomenon.' When separated from the rock and all gritty particles, most of the chrysotile-asbestos fibre exhibits extreme delicacy and silkiness to the touch; with great adaptibility for spinning. For a time, however, the fibre produced from asbestos—unlike any other, resisted all attempts in this direction; the difficulty

[1] Jones: 'Asbestos,' page 327.

[2] Mineral Physiology and Physiography '1886.'

arising from the peculiar formation of the fibres, which, possessing perfectly smooth surfaces, and being much less elastic than fibres of organic origin, slipped past each other when subjected to the spinning process. But all these difficulties have been overcome: a single thread of fair tensile strength can now be made, weighing not more than an ounce per hundred yards.

The hardness of Canadian chrysotile is from 3 to 3·5 Moh's scale, and its specific gravity 2·2 to 2·3. It has a lustre subresinous to greasy, pearly, wavy, and silky. The colour is generally dark green to blackish-green. The asbestos in East Broughton is grass green; while that from Templeton is yellow—sometimes having a pale green tint. Blue asbestos has been found in Canada in one place only: in a shaft 60 feet deep in Templeton; but this is an exceptional occurrence. In most cases, however, the fibre, when drawn out in threads, is white, with silky lustre. Brown and discoloured asbestos is also found, but this colour is not original, and must be attributed to the weathering process, or to infiltration of other substances, mostly oxide of iron.

Temperatures of 2,000 to 3,000 F are easily withstood, while with some varieties a temperature of 5,000 F has apparently produced no visible effect. As to acid resisting qualities, F. Schrader[1] states that hornblende (amphibole) asbestos is preferable in this respect to the chrysotile variety: he finds that asbestos fabrics, in order to resist such acids as are required in the chemical industry, should be made of hornblende asbestos, in which the proportion of bases to silica is 1:1. Chrysotile-asbestos, in which the proportion of bases to silica is 3:2, is attacked by very weak acids (like acetic acids), which dissolve the bases, and leave almost pure silica, without apparently destroying the fibrous condition. Boiling for four hours with dilute hydrochloric acid effects the same result.

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[1] 'Chemiker Zeitung' 1897, page 285.

Chemical Composition of Chrysotile.—In determining the value of asbestos, chemical analysis is a very important factor; since the chemical percentage composition of good spinning fibre remains always within a certain limit. With a view to studying this question more fully, the writer has had a number of asbestos specimens from Canada and elsewhere analysed, and these results—together with those of other analysts—are given in the following table:—

Locality.	SiO_2	MgO	FeO Fe_2O_3	Al_2O_3	H_2O	Total.	Authority.
Thetford	39·05	40·07	2·41	3·67	14·48	99·68	Dr. J. T. Donald, Montreal.
Black Lake (Amalg. Asb. Corp.) B.C. quarries.	39·36	42·15	3·31	....	14·50	....	Dr. Milton Hersey, Montreal.
Black Lake (Amalg. Asb. Corp.) Standard quarries.	40·42	41·85	2·60	0·82	14·37	....	"
Black Lake, Southwark mine.	39·22	40·27	2·26	3·64	14·57	....	Dr. J. T. Donald, Montreal.
East Broughton (exact locality not given).	40·87	41·50	2·81	0·90	13·55	99·63	"
East Broughton, Glasgow and Montreal mine.	41·90	42·50	0·69	0·89	14·05	....	"
East Broughton (Frontenac)	39·20	42·97	2·95	....	13·87	....	Dr. Milton Hersey, Montreal.
" " ..	(Not	determi	ned.)	....	14·50	....	"
Eastman (Benoit location).	40·42	40·62	2·92	1·92	13·45	....	"
Danville	41·84	41·99	2·23	....	14·28	....	Dr. J. T. Donald, Montreal.
"	42·64	39·54	3·66	....	14·31	....	"
Laurentian (Templeton)...	40·52	42·05	1·97	2·10	13·47	100·10	"
Italy	40·30	43·37	0·87	2·27	13·72	100·53	"
Western Australia.......	42·20	40·73	2·08	1·60	14·01	....	Dr. Milton Hersey, Montreal.

Note.—The special point to be observed in the above table is, the variation in alumina: which ranges from 3·64 per cent at Black Lake, to none at Danville.

A most interesting feature in connexion with these analyses is, the great similarity of the percentage composition of fibre: which outwardly shows the qualities of great silkiness, flexibility, and strength. It is also found that the amount of water varies only between 13·47 and 14·50. The inference, therefore, is, that good, commercial, asbestos fibre, be it 'hornblende' (like the Italian), or 'chrysotile' (like the Canadian), contains always a certain amount of water, which, as the analyses indicate, does not fall below 13 per cent; while all the harsh, brittle fibres of the tremolite and actinolite, and also some of the hornblende group, contain little water: the amount varying between 1·1 and 5 per cent.

That the percentage of water has a great deal to do with the silkiness of the fibre, is shown in the physical change of fibre when the latter is heated to a temperature that will drive off a portion of the water. The remaining substance is so brittle, that it may be crumbled between the finger and thumb. Experiments have demonstrated that a high degree of heat will cause the asbestos fibre to become brittle, although it does not destroy its heat resisting qualities. It

is probable that the brittleness observed in chrysotile-asbestos is chemically a hydrous magnesia silicate, represented by the formula $2H_2O$, $3MgO$, $2SiO_2$. The two parts of water are not present in the form of moisture, which could be readily driven off at a temperature of 212 F, but in a chemically bound state, and can only be eliminated at a high temperature, leaving a compound consisting of magnesia and silica. This alteration in the chemical composition of the material would change, to some extent at least, its physical character; and it is probable that it is the direct cause of the loss of strength of the fibres. Owing to the destruction by bush fires of the forests covering the knolls of serpentine in the Eastern Townships of Canada, some of the asbestos fibre in Thetford and Black Lake is harsh and brittle, especially near the surface, changing sometimes to greater softness as the veins are opened out deeper, or away from the surface. It is also probable that the harsh fibre was, as originally deposited, soft and flexible, and has been rendered brittle by having a portion of its water driven off by heat; produced either by the movement of the associated rocks, or resulting from the injection of molten matter through volcanic action. Veins at considerable depth may have been subjected to the heat produced by these rock movements, and yet not deprived of any portion of their original water, because of the resistance of the overlying rocks.

Lime Asbestos.—A peculiar variety of chrysotile-asbestos of little commercial value was found on lot 14, range XI, Broughton. A further description of this is given on page 63. On account of the large content of lime, which differentiates it from 'chrysotile,' the writer has named this variety 'lime asbestos.'

Summary.

With a view to affording a better understanding and conception of the various minerals generally grouped under the term 'asbestos,' a recapitulation of all the facts may be advantageously presented.

The name *asbestos* as commercially used at the present time embraces three minerals with a number of subdivisions, having in common a fibrous structure, and possessing more or less fire and acid proof properties. These minerals are enumerated in the following table:—

(I.) The Anthophyllite group. Chemical composition (Mg, Fe) SiO_3.

(II.) The Amphibole or Hornblende group. Chemical composition $RSiO_3$; usually associated with oxide of iron and manganese, and in a general way analogous to the pyroxenes; sodium and potassium are also present:—

(*a*) Tremolite.

(*b*) Actinolite.

(*c*) Hornblende asbestos, hydrated (Italian asbestos).

(*d*) Mountain leather, mountain wood and cork.

(*e*) Crocidolite (blue or African asbestos, from West Griqualand).

(III.) Serpentine group $3MgO$, $2SiO_2$, $2H_2O$, or hydrated silicate of magnesia.

(*a*) Picrolite: found in Canadian mines.

(*b*) Chrysotile-asbestos, as found in Canadian mines.

(*c*) Talc.

All these minerals resemble each other chemically, and the following table (computed from Dana) shows their average theoretical percentage composition:—

—	Actinolite.	Asbestos.	Chrysotile.	Talc.
Silica	57·13	57·82	43·56	61·95
Alumina	1·15	0·43	0·52	0·98
Ferrous oxide	6·39	5·23	1·60	1·91
Manganese oxide	0·65	0·66		
Magnesia	20·66	21·86	41·36	30·87
Lime	13·28	13·98		
Water	1·57	0·77	13·79	4·08
	100·83	100·75	100·83	99·79

In external appearance, and in chemical composition, they are much alike: indeed so much so, that when the crystals occur in long, slender prisms, or in radiating masses, the mineral is called actinolite; but when found in long, slender, flexible fibres easily separable, it is named asbestos. The difference between good and bad asbestos can be at once perceived by subjecting the fibres or long, slender crystals to tearing, twisting, and bending between the fingers. The good asbestos, applicable to the finer purposes of manufacture, will give up silky threads of great elasticity, and amenable to the various spinning processes; while bad asbestos will split up into harsh and sometimes brittle fibres, occasionally breaking up when rubbed between the fingers.

The heat resisting property of both of these varieties of asbestos is approximately the same; so that when this characteristic of the asbestos is the only quality desired, the amphibole variety is found to be equally as satisfactory as the chrysotile; but whenever strength of fibre as well as nonconductivity of heat is desired, the chrysotile variety is the only one that can be used to advantage. Chemically the two species are much alike: chrysotile-asbestos is a hydrous silicate of magnesia, while the amphibole varieties are all either silicates of lime and magnesia, or compounds of silica with an earthy base—part of them hydrated. A special feature to be noted is that, none of the anhydrous varieties have much of the unctuous feel which is so common a characteristic of the serpentine species.

CHAPTER II.

GEOLOGY OF THE CANADIAN SERPENTINE AREAS.

Inasmuch as the study of the occurrence of asbestos ores involves an investigation of the serpentine rocks, the writer, before entering into a consideration of the deposits—as such, has deemed it advisable to set forth a brief description of the various serpentines found in southeastern Quebec: based upon investigations made by Messrs. N. Giroux, Dr. Bayley, Dr. Bell, Dr. Harrington, Hugh Fletcher, Dr. R. W. Ells, Dr. A. P. Low, and Dr. Frank D. Adams—also his own—covering a period of over twenty years.

The most important, and the one which is also the most interesting from a geological point of view, is the Archæan group of serpentines, consisting of the Laurentian, the Huronian, and the Cambrian serpentines.

Laurentian Serpentines.

The Laurentian serpentines are confined to the great Laurentian formation which covers the larger part of eastern Canada. They are mostly associated with crystalline limestone, and occur in the latter disseminated in grains varying in size;occasionally in scattered masses; and sometimes in interstratified beds. As a general rule these serpentines vary in colour from a light green up to very dark green shades. Pale yellow, and some greyish serpentines are very frequent; they contain occasionally red patches caused by the decomposition of iron pyrites present in the rock. The Laurentian serpentine contains less oxide of iron and more water than ordinary serpentines.

The most easterly occurrence of Laurentian serpentine is near Pisarinco cove, New Brunswick: where crystalline limestones, grey, and beautiful white, alternate with quartzites, and diorites, and sometimes with argillites. Amongst these rocks serpentine can be perceived very frequently, but it does not occur in large masses. At one point, limestone is enclosed in a bed of diorite, and both rocks are traversed by veins of serpentine containing 'chrysotile-asbestos.' On the west side of the narrows of the St. John river, small patches of serpentine can be noticed in crystalline limestones, with a conglomerate of limestone pebbles.

Farther westward in the Ottawa valley, in the townships of Grenville and Templeton, there has been quite a development of crystalline limestone containing scattered masses of serpentine of irregular ellipsoid form.

Serpentine rocks similar to those mentioned are found in the Seigniory of La Petite Nation, which adjoins the township of Grenville. In the vicinity of Calumet falls, on the Ottawa river, pale green serpentine, associated with brown phlogopite and apatite in the white crystalline limestone, occurs quite frequently. Still farther westward, crossing the Ottawa river, we find serpentine in the township of Ramsay, Lanark county, Province of Ontario, about thirty

miles southwest of the township of Templeton. The surface of the serpentine in the latter vicinity is of a beautiful amber colour, but in most places the mineral is disseminated through a white crystalline limestone. In Lanark township serpentine is interstratified with limestone, and forms a rock of striking beauty. In the township of Dalhousie, on lots 23 and 24, concession III, the serpentine is interlaminated with a granular crystalline limestone. Farther south of the township of Dalhousie, in the township of South Sherbrooke, spotted serpentine limestone resembling those at Templeton may be noticed. In North Burgess, adjoining Dalhousie township, an almost pure serpentine has been found. About twenty miles farther south, in the township of Loughborough, county of Frontenac, white, and coarsely crystalline dolomite is seen on lot 4, concession X; also in Wollaston or Hatchet lake; and at the head of Reindeer lake, serpentine of probable Laurentian age is reported to occur. Dr. A. C. Lawson, of the Geological Survey, reports having met serpentine in the Keewatin area, on the west side of Clearwater lake, a tributary of Rainy lake. This rock is massive, and occurs there in a band, immediately followed to the west by hornblende schist, and to the east by another band of green hornblendic schists and altered traps. Another mass of serpentine, in a very analogous position, is seen on South bay of Lake Despair, and Dr. Lawson reports this as occurring with some degree of persistency in the middle portion of the Keewatin trough, and thinks these serpentines are the altered remains of olivine rocks. A small boss of this rock was also examined by Dr. Lawson at the southwest end of Sucker lake, coming in with green schists.

Mr. W. S. Bayley, of the Geological Survey, has made microscopical examinations of these serpentines, and says that in many of them the forms of the original olivine can be clearly seen, although there is no trace of the mineral left. Dr. Lawson reports serpentine to be more largely developed on the island and shore of Shoal Lake narrows than elsewhere in the Lake of the Woods region. He mentions also a boss of serpentine projecting through the black hornblende schists in the immediate vicinity of their contact with the gneiss.

Many minerals are associated with the Laurentian serpentine, but very few are in workable quantity.

Small quantities of chrysotile have been mined for asbestos in the township of Templeton, but the fibre was so short, that these works were soon abandoned. Further particulars about this chrysotile-asbestos will be found on pages 36 to 40.

The magnetic iron ore formerly smelted at the Marmora iron furnace was obtained from lot 8, concession I, of Belmont. This deposit consists of a succession of beds of ore, interstratified with layers of greenish talcoid slate and crystalline limestone: with which are associated serpentine, chlorite, diallage, and a greenish epidotic rock. Iron of a superior quality was manufactured from the ores of this deposit.

Pyrallolite, a mineral similar to steatite in chemical composition, softness, and refractory properties, is often met with in the Laurentian series. A bed of it, associated with serpentine, occurs between the gneiss and the limestone on lot 13, range V, of Grenville. It may be traced from thence into range VI,

and appears to be in considerable quantity. The colour of this mineral is generally greenish-white, or sea-green; some varieties of it being nearly white, and having the translucency of porcelain. Very dark coloured, nearly black varieties, have also been found, and this mineral is capable of being turned in a lathe and worked like soapstone: having been made into small vases, ink-stands and similar articles. Much of the figure-stone, or 'pagodite,' which is carved by the Chinese into various ornaments, appears to be pyrallolite. It was used by the aborigines to make pipes and ornaments.

The serpentine of lot 13, range V, Grenville, and of some parts of the township of Burgess, is of a pale green colour, marked with spots of iron oxide, and forms a fine ornamental stone.

Inasmuch as serpentine has been used for various commercial purposes, and sometimes in large quantities—especially as a plaster and roofing material—it may be of interest to give some additional information regarding its physical and chemical properties.

The Laurentian serpentines have a lower specific gravity and contain less oxide of iron and more combined water than ordinary serpentine. The following analyses of some of them show their chemical composition[1]. No. I is from Grenville, taken from a white crystalline limestone; its colour varies from honey yellow to oil green, and its density is 2·47—2·52. No. II is a similar serpentine of a pale wax yellow, from Calumet island; its density is 2·36—2·38. No. III consists of grains of honey yellow serpentine, separated by dilute nitric acid from a white lamellar dolomite from Grenville. No. IV is the reddish brown serpentine rock, or ophiolite of Burgess:—

Constituents.	I.	II.	III.	IV.
SiO_2	39·34	41·20	44·10	29·80
MgO	43 02	43·52	40·05	38·40
$FeO+Fe_2O_3$	1·80	0·80	1·15	7·92
H_2O	15·09	15·40	14·70	13·80
	99·25	100·92	100·00	99·92

Chrysotile-Asbestos in the Laurentian.

The presence of asbestos in the crystalline rocks of the Laurentian formation has been known for over forty years, and mining was attempted from time to time, but was found unprofitable, owing to the limited extent of the deposits. But as there still appears to be some difference of opinion regarding the character of these deposits, the writer—who has spent several years in their investigation—will give a brief résumé of the operations conducted in that locality and the results obtained.

[1] Geological Survey, 1863, page 472.

CHARACTERISTICS OF THE LAURENTIAN DEPOSITS.

In the Laurentian formation, the serpentine in which asbestos occurs is closely associated with the crystalline limestone that traverses the gneiss in the form of bands in a generally northeast, southwesterly direction. These crystalline limestone bands occur at intervals, and constitute one of the main parts of the so-called Grenville series: extending from Ottawa eastward for several hundred miles. The occurrence of asbestos serpentine, however, is so far restricted to the country north of Ottawa. The following is a description of the occurrences, and of the operations carried on in the township of Templeton.

DESCRIPTION OF TYPICAL OCCURRENCES AND OPERATIONS ON LOT 11, RANGE VII, TOWNSHIP OF TEMPLETON, FIFTEEN MILES NORTHEAST FROM OTTAWA.

The rock in which the asbestos serpentine deposits occur forms a large stratum of massive crystalline limestone, about 700 feet wide, striking in a northeast and southwesterly direction, bordered on both sides by red, grey, and white orthoclase gneiss. The crystalline limestone contains a number of accessory minerals, such as small crystals of mica, iron pyrites, small veins of graphite, pockets of hematite; while grains of serpentine are disseminated through the whole rock. The asbestos deposits frequently assume the form of concretionary masses, sometimes like rounded boulders; as disconnected patches or pockets of small extent, from 12″ up to 3 feet diameter; as irregular masses of limited extent; and as deposits with ring-like or elliptical sections, having a diameter from 3 to 50 feet, and serpentine walls varying from 6″ up to 3 feet thick. (See Fig. 1.)

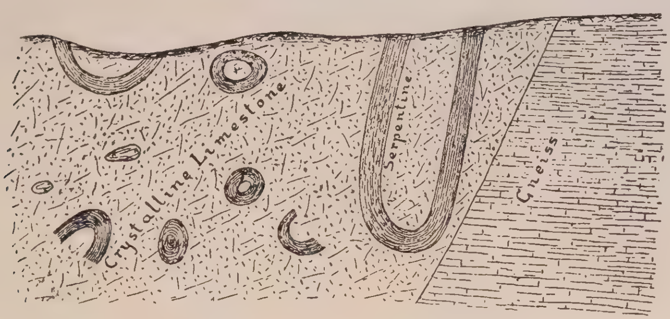


FIG. 1.—Laurentian asbestos deposits.

They sometimes present masses of yellowish green, spotted with crimson or blood red patches formed by disseminated peroxide of iron.

The general outline of these deposits on the surface is in the form of an ellipse; though in different places straight veins of small extent have been observed. In the elliptical deposits, a sharp, defined line can be recognized between the deposits and the associated limestone, and the veins generally follow the contours of the deposits.

The serpentine has a light green, yellow green, and dark green colour; but it is difficult to say which is the characteristic colour for the occurrence of asbestos. A greyish green colour is very often seen in the larger deposits. Small fissures through the serpentine—caused by the mechanical action of the water—are very numerous, and for this reason the material splits up, hence can not be obtained in dimensions suitable for ornamental purposes. The fresh serpentine contains much water, and is easily separable from the asbestos. Some light green varieties are soft, and have a peculiarly unctuous aspect.

Asbestos is found in small veins or layers, usually following the contours of the outer coat of the serpentine deposit, and ranging in thickness from a fraction of an inch to half an inch, and sometimes even more. They run in parallel layers, which may split up and form a larger number of veins, or coalesce. The veins are sometimes displaced out of their natural positions and cut off by faults, as observed in several places; but such a displacement is seldom larger than 6 feet. In many cases, instead of fibrous veins, asbestiform matter of a white colour, and of the same characteristic structure, is met with. It has an unctuous aspect, and shows, occasionally, the gradual change to the fibrous variety. The asbestos itself has a very fine, silky fibre, and is admirably adapted for spinning. It has a marked wavy lustre, and light yellow, light green colour —seldom a dark green, and is very transparent: a sure indication of the absence of impurities. Chemical analysis shows that the Laurentian asbestos contains very little oxide of iron: much less than any other asbestos found in Canada. Black-blue varieties with a very silky fibre of from 1½″ to 2″ long, have been observed in one place only, at a depth of 60 feet. This is, however, an exception to the general rule.

As to the number of these asbestos serpentine deposits, they are irregularly distributed through the whole limestone strata; but on account of the lack of leading indications it is difficult to say which part of the limestone contains workable deposits, even if the asbestos outcrops on the surface. As an illustration of this fact it may be mentioned that, in one place five deposits were outcropping on the surface, containing fibre measuring from ¼″ to 1¼″ in length, and the opinion prevailed that this spot—according to these indications—probably contained workable deposits. Upon exploiting the latter, however, it was found that all the veins were of very limited extent, and on account of the concretionary form of the deposits they terminated at a depth of 10 feet. Sinking further, to a depth of 40 feet, revealed nothing of value, except some beautiful coloured masses of serpentine.

Amongst the deposits found on this property there was one specially remarkable. This deposit—which outcropped on the surface in elliptical form, with the larger diameter 50 feet, and serpentine walls of a width of 2′–6″ to 3 feet, and containing excellent fibre of from ¼″ to 1½″ in length—continued to a depth of 60 feet, in great regularity. At this depth a drift was run along one of the walls, and it was found that the character and horizontal extension of the deposit were precisely similar to those exposed on the surface. In sinking, however, the asbestos veins gradually disappeared, the serpentine

being broken up into smaller pockets and bunches, containing here and there a few small stringers of the mineral. Most of the other deposits found on this property did not show a larger diameter than 20 feet. It was often observed that, asbestos of 1″ and 2″ in length on the surface, disappeared when the vein was followed towards depth.

The percentage of fibre in the serpentine, as determined by the writer in the mills at Buckingham, was very satisfactory: sometimes more than 15 per cent of the milling material; but the latter was not plentiful, and the bulk of fibre extracted was small.

The deposit at Denholm, near the Gatineau, is similar to that in Templeton as regards the mode of occurrence; but it appears that at one place the accumulation of asbestos deposits was large, and warranted, for some time, the expenditure in quarrying. It is reported that from one shaft which was sunk to a depth of over 160 feet in one year, 25 tons of fibre and crude, and 850 tons of asbestos cement of very fine quality were produced, and that a profit of $6,000 was made, after paying all expenses.

LOCALITIES OF LAURENTIAN CHRYSOTILE-ASBESTOS.

Among the many localities where the Laurentian asbestos has been found to occur, the following may be mentioned:—

Township of Portland West, county of Ottawa, lot 16, range V. The chrysotile occurs in two principal bands, one of which is near the brow of a ridge of limestone, having a band of serpentine near the contact with the gneiss and with a dike of white granite or pegmatite along the contact. The elevation of this ridge is about 60 feet above the road. At its base, and in the serpentine band there are from twenty-five to thirty small veins in a space of 2 to 3 feet. Most of these are mere threads, but some reach a thickness of ½″ or even more. The band of limestone is here exposed for a breadth of about 150 yards, and a second narrow band of asbestos-bearing rock occurs near the eastern edge of the area, which terminates against a mass of red granite-gneiss. In this area the concretionary looking masses of serpentine are not observed.

Several areas of serpentine, with small quantities of chrysotile, have been found at various points. About three miles north of St. André Avellin, Coté St. Pierre, a band of limestone occurs between two dikes of greenstone. The contact between the limestone and the greenstone (diorite) is marked by a zone of serpentine, in which small veins of chrysotile are seen. The lower portion of the limestone has small grains of serpentine distributed throughout.

Among other deposits may be mentioned: lot 14, range VII; lot 2, range VIII; and lot 16, range V, all in the township of Templeton.

In the township of Wentworth, on lot 20, range IX, south of Silver lake, the belt of crystalline limestones which extends eastward from Lost river to Sixteen Island lake, contains in its lowest part, near an intrusive pyroxene, a narrow band of serpentine with several small veins of chrysotile, on which an attempt at mining was made some fifteen years ago. Some of these veins are ½″ thick. White granite dikes occur also in the vicinity.

On Blanche lake, in the township of Mulgrave, similar serpentine deposits occur with small quantities of asbestos, as also on the east side of Grill lake; but it may be said that, of all those yet examined in this district the quantity is too small to render its extraction profitable.

Serpentine occurs similarly at several points along the Ottawa river, in the rear of 'Pointe au Chêne.' A mill was erected at this place eighteen years ago, to separate the fibre. The amount of fibre, however, was too small for successful treatment, hence the works were closed.

Mr. W. H. Collins[1] describes some occurrences of serpentine on Foot and Firth lakes, in the Gowganda Mining Division. He reports as follows:—

> 'In the Keewatin area between Firth and Obushkong lakes there occur masses of a basic igneous rock through whose decomposition serpentine and asbestos have been developed. Two bodies were found. One of these, lying east of Foot lake, and 20 chains from Obushkong, was traced for a width of 4 chains, but nothing was learned of its north and south extent. It consists very largely of green serpentine, traversed by a network of fine, white, weathering veins of asbestos. More extensive outcrops exist along the east shore of Firth lake. At somewhat more than a mile from the foot of the lake and near a small log shack at the water's edge a considerable mass of partially decomposed wehrlite, serpentine, and asbestos is visible.'

Huronian Serpentines.

The Huronian serpentines are little known, and of limited extent. According to investigations made by the Geological Survey, serpentine of Huronian age occurs at two points in Charlotte county, New Brunswick. Northeast of St. Stephen, dark grey, dioritic rocks occur, containing serpentine, diallage, and chromic oxide. About two miles north of St. Stephen may be seen ledges of coarse-grained, dark grey, granitoid diorite, having thin layers of picrolite or fibrous serpentine in the joints, as well as serpentinous matter in the body of the rock. In crossing these ledges towards St. Stephen, the rock becomes somewhat darker, and portions are met with exhibiting thin lamination; the laminæ being separated by layers of serpentine about $\frac{1}{8}''$ in thickness. There seems to be some doubt as to the age of these serpentinous rocks; and although supposed to be of Laurentian age, they are being placed under the head of Huronian rocks. The presence of chromic oxide in them and the want of crystalline limestone in their association with other rocks gives them quite a different character to those of the Laurentian series of this Province. In a northwest direction from those last mentioned, the first known outcrops of these serpentines are on Lake Abitibi, where they are found to be associated with micaceous hornblende, and chloritic schists; fine-grained hard quartzites, diorites, and dioritic schists. A little island in this lake is composed of strongly magnetic serpentine, with splintery fracture, having a resinous lustre, and weathering dull white. An analysis of it was made by Dr. Harrington, who found it to contain grains of chrome iron ore, and a very small quantity of nickel, besides silica, alumina, magnesia, and protoxide of iron.

[1] Report on the 'Gowganda Mining Division,' Geological Survey, Ottawa, 1909, p 46.

According to Dr. Bell there is, in the middle of Pigeon lake, at about one mile from the lower end of it, a small island composed of very dark green serpentine, with strings of calcspar and chrysotile. It weathers rusty, and Dr. Harrington, on analysis, found it to contain oxide of chromium both in the form of small grains, and in chemical combination with the rest of the rock.

No mineral of economic importance has yet been found in these serpentines; but perhaps when the country where they are more abundantly met with is settled, deposits of asbestos may yet be discovered.

The Pre-Cambrian serpentines seem to be limited to the almost extreme easterly portion of the Dominion. Mr. Hugh Fletcher reports serpentine to occur in three different places:—

> (1) In Macdonald brook, Cape Breton island, where white, pyritous crystalline limestone, lemon yellow serpentine limestone, and pale-green, brown-weathering limestone, and tremolite in small fibrous tufts, occur between bluish-grey and red felsite and bluish-porphyritic felsite; (2) on Kelvin brook, in the same island: a cliff of coarse, reddish felsite, associated with greenish and red, mottled, soft serpentine, is in immediate contact with reddish coarse grit and conglomerate along an irregular line which runs northeast 9°; and (3) on Campbell brook, eastern Nova Scotia: some white crystalline limestone appears, some beds of which are covered on the surface with large knobs of light-greenish and white serpentine, but the hills are composed mainly of syenite.'
>
> 'These resemble very much the Laurentian serpentines in colour and in their association with crystalline limestones. No minerals of economic value were found in them.'

Cambrian Serpentines.

The Cambrian serpentines are those which are confined to the great serpentine belt that extends from southern Vermont to Gaspé, in the Province of Quebec. They are by far the most important in the Dominion: not only on account of their very interesting geological structure, and in being an altered metamorphic rock, but because they contain economic minerals in abundance, especially asbestos, and chrome iron ore. This serpentine belt may be divided into three areas:—

(1) The area covering part of the townships of Bolton, Orford, Brompton, Melbourne, and Danville.

(2) The Thetford-Black Lake area, covering part of the townships of Ham, Wolfestown, Coleraine, Thetford, and Broughton.

(3) The area covering a part of the Gaspé peninsula.

The first area—which may be termed the southwestern area—commences with the International Boundary line in Potton, and extends through the township of the same name, through Bolton, Orford, Brompton, Melbourne, and Danville, and is characterized by a chain of hills extending also beyond the boundary into Vermont. These serpentines, which are closely allied to a contiguous band of diorite and dioritic rocks, appear in irregular, but generally well-de-

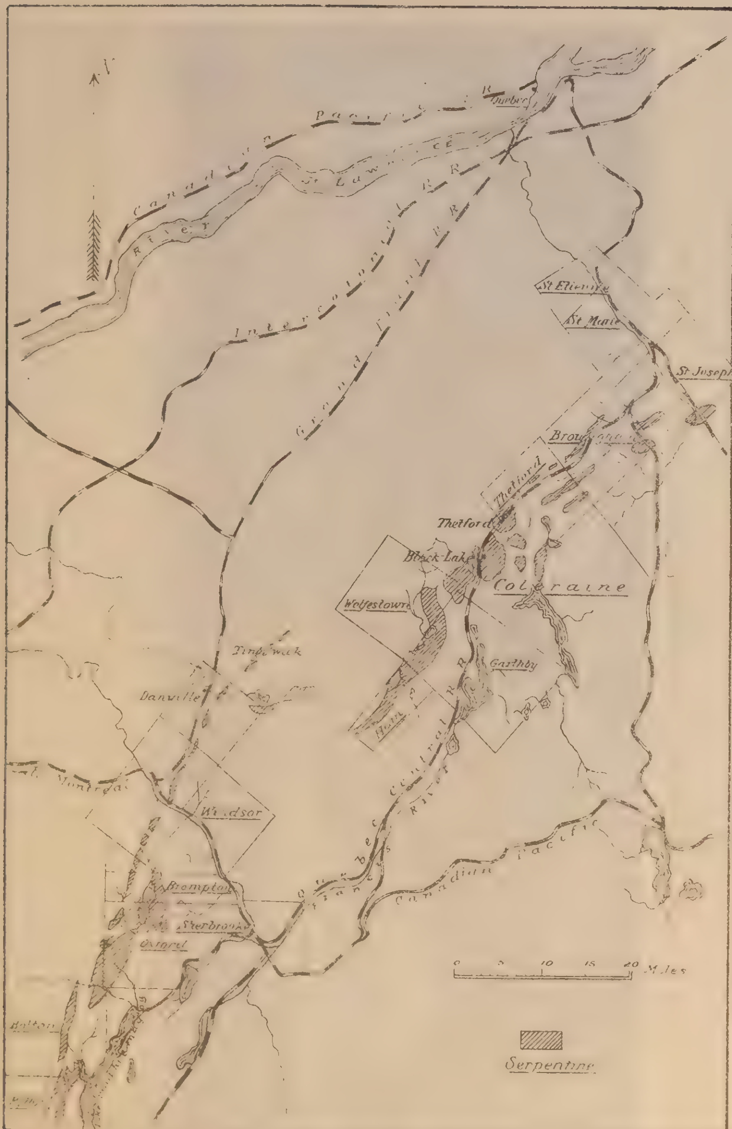
fined masses; and although showing here and there in most of that distance, they do not deviate from their northeastward direction, but follow the general trend of all the formation—which is northeast. Along the course of this belt of serpentine, chrysotile exists at different points; also in several places in the townships of Bolton, Brompton, and Melbourne. Further particulars regarding these deposits will be found on pages 77 and 78. It must be mentioned that the area under consideration is largely covered with heavy humus and forest growth, so that on this account prospecting is very difficult and almost impossible. The true value of this area as regards the occurrence of asbestos can only be surmised. It is evident, therefore, that unless the heavy forests are destroyed by fire, and the soil removed—as in Black Lake and Thetford—there is little chance that the presence of the mineral in paying quantities will ever be established.

The second, and most important asbestos field from an economic point of view, is generally termed the Black Lake-Thetford area. It commences with several small knolls of serpentine north of the Chaudière river, and in the vicinity of that river, between the villages of St. Joseph and St. Francis. In the townships of Broughton, Thetford, Coleraine, Wolfestown, and Ham, a great development of serpentine rocks can be observed: forming at times mountain masses from 700 to 1,000 feet above the surrounding country, and contributing largely to the generally rugged character of the latter by their sharp outlines and weathered surfaces. This is the largest field of serpentine to be seen along the Atlantic seaboard of North America: and, at present, the most important one in Canada; since it contains all the productive asbestos and chrome iron ore mines in the Dominion. The serpentine mountains of the townships of Ireland and Coleraine extend over a width of from five to six miles; with a spur towards Little Lake St. Francis. Small outcrops of serpentine can be noticed on the Rivière des Plantes, and in range V, of Cranborne, on the Etchemin river.

Nearly all the productive mines of asbestos are located in this region, more especially in the townships of Coleraine, Thetford, and Broughton, and although only one large workable deposit has been discovered outside this locality, at Danville, there is no reason whatever why, with extended and more vigorous exploration work, additional productive serpentine cannot be found.

Most of the serpentines that occur in the first and second areas, as described above, are associated with dioritic rocks at many points throughout the townships: sometimes in masses of large extent, as in the Big Ham and the Little Ham mountains, and in the peaks along the western side of Lake Memphramagog; also in others as dikes. With these are often associated agglomerated serpentines and serpentinous breccias.

In the third area—that of the Gaspé peninsula—the serpentine presents a very large development, especially in the Shickshock Mountain range: Mount Albert and Smith mountain. It is found in bands sometimes a few yards in width, interstratified with the slates and sandstones, and sometimes with diorites, in conjunction with which it forms knoll-like hills, or elongated ridges of considerable extent. The western portion is too hard and siliceous to give much promise of asbestos; but some portions of Mount Albert have shown small veins along with deposits of chrome iron ore.



Map No. 86.

MAP SHOWING GENERAL DISTRIBUTION OF SERPENTINE IN THE EASTERN TOWNSHIPS, QUE

BY FRITZ CIRKEL, M.E.

Black Lake village and surroundings. Milling plant of the British Canadian quarry in the background.

In the eastern portion of the peninsula, at Mount Serpentine on the Dartmouth river, a few miles from its mouth, Mr. J. Obalski[1] has discovered some veins of asbestos in a band of serpentine associated with hornblende rock. This mountain rises to a height of 1,600 feet above sea-level, and is surrounded by the sandy and calcareous beds of the Siluro-Devonian system of that region. The area under question has never been carefully explored with a view to ascertaining the presence of the mineral in quantity, owing largely to the difficulty of access.

Serpentine has been discovered in Lake Chibougamau, on Asbestus island; and judging from the little work which has been done so far, it seems that the rock containing asbestos fibre resembles very much the Black Lake-Thetford serpentine. Its extent is not known; but from reports which have been submitted to the writer, the region has been overestimated.

On the north shore of McKenzie bay there is a continuous development of fine, greenish serpentine; and Mr. Obalski entertains the opinion that, regular prospecting work might lead to the discovery of asbestos mines.

Broughton, Thetford, and Black Lake Areas.

The present workable asbestos deposits are—as far as exploration work has shown, and, with the exception of the 'Danville' quarries—confined to the great serpentine range which strikes through the townships of Broughton, Thetford, and Coleraine, in a direction northeast 85°. Leaving some scattered deposits in the townships of Wolfestown and Ireland out of consideration, the total length of this productive serpentine belt is twenty-three miles, with a

FIG. 2.—Profile of asbestos-bearing formation at Black Lake and Thetford.

width varying from 100 feet in the extreme easterly part, to 6,000 feet in the Black Lake area. The serpentine belt as a whole, however, in many places far exceeds the width indicated above. In the township of Broughton, for instance, this width ranges from 200 to 1,000 feet; while the greatest width so far determined in the township of Coleraine is 3½ miles. In presenting a geological description of this serpentine range, which has become famous by reason of its unlimited supply of the finest quality of asbestos; it must here be stated that, the main objective in its examination was, to find out whether

[1] Inspector of Mines, Province of Quebec.

the deposits scattered over the country—especially in Broughton and Thetford—constituted parts of a continuous belt. If this were found to be the case, it would be a great incentive to exploration, and probably lead to the discovery of new deposits. In the investigation of this serpentine belt many new facts have been brought to light: especially with regard to their individual richness; their extent; their general character; their relation to the country rock; and the quality of the asbestos disclosed in different parts of the range.

The productive serpentine of the Eastern Townships is confined to the southeasterly part of what is now generally considered as the Cambrian formation: which occupies the greater part of that section of the country. This southeasterly part has a width of from five to fifteen miles: commencing in the townships of Shipton and Ham, and continuing in a northeasterly direction, beyond the Chaudière river, into the county of Bellechasse.

The metamorphic character of the rocks constituting this formation precludes the discovery of traces of organisms; in fact, great thicknesses of strata examined are, apparently, devoid of any sign of past organic life. The Cambrian rocks so far met with—more especially in the serpentine region now under consideration—consist of quartzites, impregnated heavily with small pockets and veins of quartz; greenish chloritic schists and slates, and mica schists. At several places a sub-crystalline limestone cuts through the series: in the township of Broughton, along the road to West Broughton, from Broughton station, and also north of Beauce Junction. In all these localities they are associated with black slates and quartzites, and have been burned for lime. To the northwest, this southeasterly part of the Cambrian series is underlaid by the rocks of a central anticlinal: the Pre-Cambrian, which constitute the oldest rocks in the Eastern Townships. The anticlinal axis of this series has a general northeasterly trend: commencing at the townships of Wolfestown and Halifax, and continuing through Leeds township to the Chaudière river, thus forming the nucleus along which the rocks of this series are grouped. The rocks which constitute this Pre-Cambrian system are composed mostly of altered sedimentary rocks or chlorite, micaceous schist, slates, sandstones, etc.—as may be observed in the townships of Ireland, Inverness, and Leeds; also of green slates, sometimes dark coloured and highly schistose, with a great variety of quartz in irregular veins.

Volcanic rocks are frequently met with in the Cambrian, and they constitute in the majority of cases the lofty peaks which rise so abruptly above the surrounding country: for instance, Broughton mountain, located in the southerly corner of the township of Broughton; and Moose mountain, in the northwesterly part of the township of Cranbourne, and several others. These volcanic rocks are composed mostly of trap rocks, of greenish, greyish, or brownish colours.

The serpentine rocks may be found in almost any portion of this easterly part of the Cambrian formation; and they are invariably associated either with quartzitic rocks or with the greenish schists, or dark slates. The productive serpentines are, as a general rule, associated with two different groups of rock: namely, the concretionary, and the massive diorites or black or greenish slates,

with hard schistose quartzites and greenish schists, as in the townships of Coleraine, Thetford, and Broughton. Small areas of serpentine are also associated with chloritic and mica schists, and in a few localities with talcose minerals like soapstone. The latter are very conspicuous in Leeds, also in Broughton and Thetford townships.

As to the physical aspect and configuration of the country which the productive serpentine traverses, it may be described as essentially 'a miners' country.' Mountain ranges of considerable height and lateral extent alternate with low lying narrow river valleys: their general direction being southwest northeast. Great fires have at times swept over this country, and denuded it of its dense forest growth: destroying everything in its path: sometimes causing the disintegration of rocks, which facilitated the prospectors' work. This, and the fertilizing effect of the alkalis left by the burning of the wood and coarse stubble growths, has doubtless been the main reason why the available ground along the wide, gently rising mountain slopes suitable for agricultural pursuits, has been so quickly taken up. The scenery of the rolling benchlands and hills, with their variously coloured landscape in the summer, is very picturesque and pleasing.

Rock Forming Minerals of the Serpentine Range.

As mentioned on page 23, serpentine is a hydrated silica of magnesia resulting from the alteration of magnesian rocks, infusible, and as a rock proper, without crystallization: its formula is $3MgO$, $2SiO_2$, $2H_2O$, that is, silica 44·1, magnesia 43·00, and water 12·9=100. It is a hydrated peridotite;[1] because it sometimes exhibits the characteristic form of crystals of peridotite, the essential constituent of which is olivine. In the latter, under the action of carbonated or heated waters containing silica, the iron instead of being peroxidized is frequently carried off: some of the magnesia being removed at the same time; the resulting rock-mass is serpentine.

The process of alteration can be illustrated by the following equations. In the case of alteration through carbonic acid waters:—

$$2Mg_2\,SiO_4 + 2H_2O + CO_2 = H_4\,Mg_3\,Si_2O_3 + MgCO_3,$$

and in the case of alteration through heated waters containing silica:—

$$3Mg_2\,SiO_4 + 4H_2O + SiO_2 = 2H_4\,Mg_3\,Si_2O_9.$$

From the first equation it would appear that magnesite $MgCO_3$ is a frequent associate of serpentine as a result of the alteration of the original rock mass; but in the Eastern Townships very little magnesite is met with, and it has evidently been taken into solution by a surplus of carbonated waters.

The rock minerals which constitute the serpentine formation in the Eastern Townships, are generally distinguished as:—

Dunite: Olivine alone and its alteration product—serpentine.

Pyroxenite: Pyroxenes alone, and

Peridotite: Pyroxenes and olivine.

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[1] Derived from 'Peridot' the French name for olivine.

Occasionally all three minerals occur independently of each other; also together in the transition stage from one mineral to another. Megascopically it is difficult to distinguish one from another; but they can be readily recognized when submitted to microscopic examination. It may be affirmed that, the first essential requisite in the formation of asbestos fibre is the complete alteration of the dunite into serpentine; if there is no alteration, there is no asbestos; which explains the existence of barren stretches of serpentine, devoid of any asbestos fibre.

In the great vein fibre belt the asbestos veins are invariably embedded in seamy rock partings, which intersect the serpentine in almost every direction. Many of these carry minute veins of the fibred material, of little commercial use, but the majority of them contain veins from ½″ to 2″ and 3″ wide. They easily separate from the rock-mass, are highly fissured, and when exposed to air for some time tarnish a peculiar white, sometimes bluish-white colour. Examination under the microscope of the rock sections constituting these partings, shows that they constitute complete alterations from dunite (olivine) into serpentine. Farther away, however, from the partings, the rock, as a general rule, is composed of pyroxene and olivine.

The writer has had quite a number of slides made of serpentine rocks taken from the partings, and at about 15″ to 18″ away from them—under the microscope, the difference in the alteration in both classes of specimens is rather striking. These slides were submitted to the Mines Branch for examination; and Dr. Alfred W. G. Wilson, of the staff, summarized his observations in the following points:—

(Plate No. VI.)

Sample taken near to asbestos vein, Dr. Reed's mine, Black Lake.

'Serpentine formed by the alteration of olivine. Small masses of magnetite appear in the upper right hand corner of the plate.'

(Plate No. VII.)

Sample taken at a point 18″ from seamy parting.

'In the centre, and completely surrounded by olivine, are two crystals of a partly altered orthorhombic pyroxene, now bastite. The olivine is traversed by a network of fractures. Serpentinization has taken place only along the fracture lines.'

(Plate No. VIII.)

Sample taken from seamy parting close to asbestos vein, property of the Imperial Asbestos Company, Black Lake.

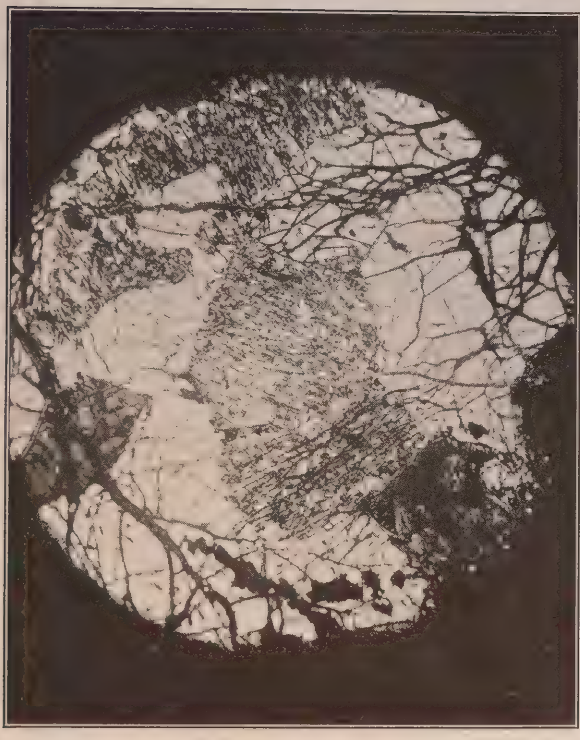
'Bastite, a groundmass of serpentine, derived from olivine. The whole section is traversed by minute veins of asbestos. All of the original mineral constituents of the rock appear to have been altered.'

(Plate No. IX.)

Sample taken from point 18″ away from seamy parting.

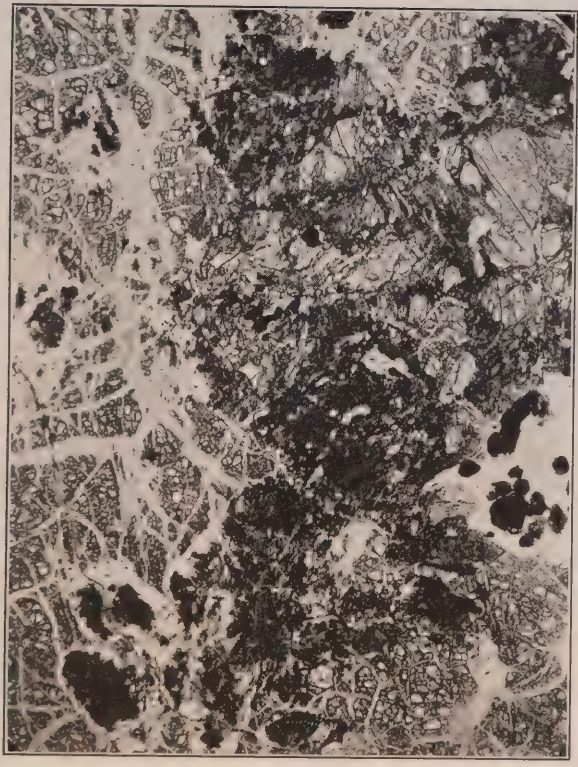
'The alteration of the mineral constituents is not complete. Small cores of olivine are seen surrounded by serpentine—particularly along the left side of the photograph. The central portion consists largely of bastite. There are

Microphotograph of serpentine close to asbestos vein, Dr. Reed's mine. Magnified 50 diameters. For description see page 46.



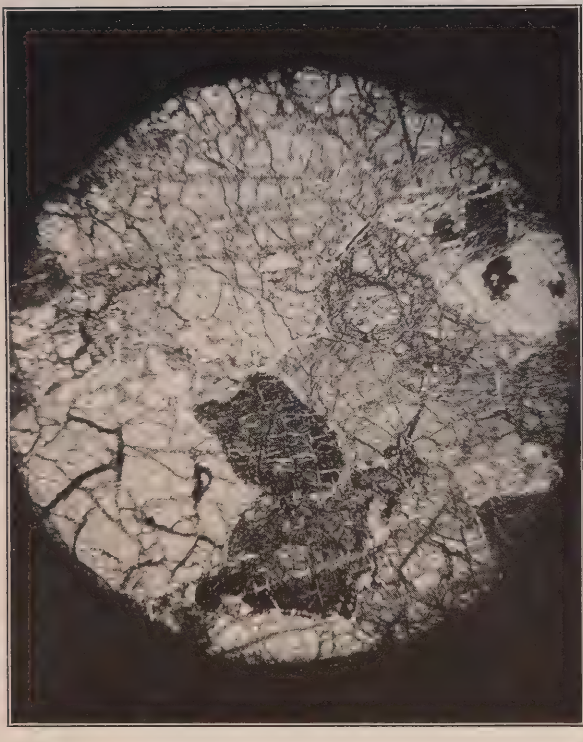
Microphotograph of rock 18 inches away from asbestos vein. Magnified 35 diameters. For description see page 46.

Microphotograph of serpentine close to asbestos vein, Imperial Asbestos Co., Black Lake. Magnified 20 diameters. For description see page 46.



Microphotograph of rock 18 inches away from asbestos vein. Magnified 20 diameters. For description see page 46.

Microphotograph of serpentine close to asbestos vein, Southwark mine, Black Lake. Magnified 35 diameters. For description see page 47.



Microphotograph of rock 15 inches away from asbestos vein. Magnified 35 diameters. For description see page 47.

p. 47

Microphotograph of serpentine close to asbestos vein, Standard quarry. Black Lake. Magnified 20 diameters. For description, see page 47.

Microphotograph of rock 15 inches away from asbestos vein. Magnified 40 diameters. For description, see page 47.

also a few particles of magnetite and some chromite shown, but the latter is not distinguishable in the plate.'

(Plate No. X.)

Sample taken from seamy parting containing asbestos vein. Southwark, Black Lake.

'The rock has been almost completely altered to bastite and serpentine. The two large crystals on the lower left hand side are bastite.'

(Plate No. XI.)

Sample taken from a point 15″ away from seamy parting.

'Serpentinization has only taken place along the fracture lines through the olivine. In the section a few crystals of a rhombic pyroxene, altered to bastite on the margins, also occur.'

(Plate No. XII.)

Sample taken from seamy parting containing asbestos vein. Standard Quarries, Black Lake.

'The rock has been completely altered to serpentine with the liberation of a small amount of magnetic oxide of iron.'

(Plate No. XIII.)

Sample taken from a point 15″ away from seamy parting.

'Small anhedra of olivine forming cores in a mass of serpentine. Small particles and strings of magnetite occur throughout the section.'

Under the microscope, olivine appears to be sometimes full of fissures, along which the alteration into serpentine takes place. This has the appearance of a finely fibrous fringe, and the fibres as a general rule are at right angles to the boundary planes. This forms the nucleus of serpentinization; the latter proceeding gradually until the whole is converted into a mass of serpentine with fibres irregularly distributed throughout. Under the microscope it can often be noticed that whenever olivine crystals have undergone partial decomposition, irregular cracks are formed, which are filled with asbestos; the fibres being arranged in the manner above described.

Chemical Composition of Cambrian Serpentine.

All that has been said regarding the physical and chemical qualities of serpentine in general on pages 22 and 23 may be applied to Cambrian serpentine in particular. A number of analyses of serpentine of the Eastern Townships is subjoined:—

Localities.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	H_2O	Authority.
Serpentine from Black Lake..	39·60	1·45	3·74	0·99	40·71	12·98	Dr. M. Hersey
" " " " ..	41·20	0·53	3·75	0·99	40·96	13·73	" "
" " " " ..	38·90	2·01	3·53	4·44	42·93	8·47	" "
" " Thetford....	39·20	0·99	2·97	4·02	44·02	8·85	
Serpentine from East Broughton (not associated with "slip" fibre).........	41·10	1·02	2·58	0·99	42·39	12·10	" "
Serpentine from Mansonville, Que..............	37·80	1·83	7·27	0 80	38·52	13·46	" "
Serpentine from Benoit location, Eastman district.	36·00	1·55	9·55	2·33	37·65	12·48	" "
Serpentine from Richmond...	38·00	2·89	7·49	1·32	38·92	10 90	" "
Fibrous serpentine from lot 2, range V, Thetford.........	40·76	....	3·05	0·49	42·32	13 60	
Lime serpentine from lot 14, range XIII, Broughton ...	41·15	13·21	2·52	10·82	12·77	3·40	
" " " ..	46·60	3·44	2·70	12·35	11·87	2·92	

These analyses will serve to show the general character of the serpentines in different parts of the Townships. The chemical composition of the respective samples is somewhat variable: the general predominance of magnesia and silica being significant; while the content of Fe_2O_3 seems to increase in the varieties which, so far, have not been proven to contain asbestos in paying quantities. A considerable decrease in the content of water and magnesia, with a corresponding increase in lime, alumina, and iron is noticeable in the 'lime' varieties of serpentine.

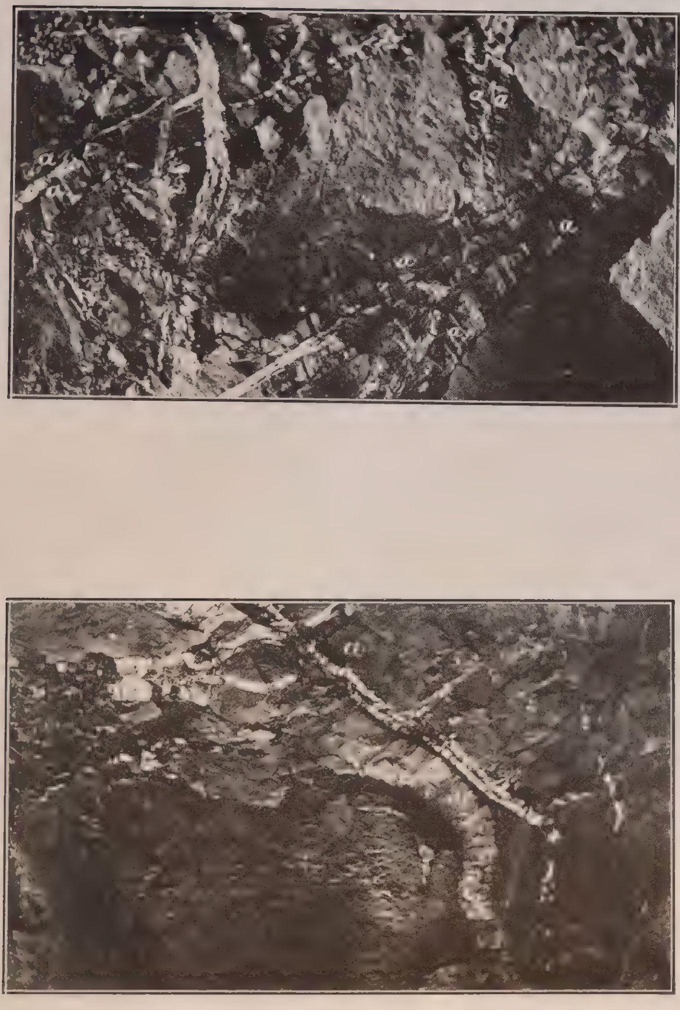
Before dealing with the asbestos belt proper it will be necessary to call attention to two different conditions in which the chrysotile-asbestos is met with in the Eastern Townships, namely:—

Vein Fibre and Slip Fibre.

The term 'vein' fibre is applied to the deposition of asbestos fibre in fissures at right angles to the enclosed walls: forming regular veins. These veins intersect portions of the serpentine in every direction; no matter whether there are folds or bedding planes in the enclosing formation: indeed they occur without any special arrangement, cutting each other also; but as a general rule they follow straight lines.

Sometimes they split up in several smaller veins, or coalesce and form a larger vein. Certain peculiar arrangements, however, can be perceived in some of the areas: at, for instance, the King quarry, in the township of Ireland, where the serpentine appears to be regularly stratified almost in the manner

Peculiar forking of chrysotile-asbestos veins.



Seamy partings (a) containing asbestos veins, from Southwark Mines, Black Lake Consolidated Asbestos Co.

of sandstone or quartz in layers—dipping to the northwest; while the veins of asbestos apparently follow what in sedimentary rocks would be regarded as bedding planes. In several other places the veins cut the rock in an almost

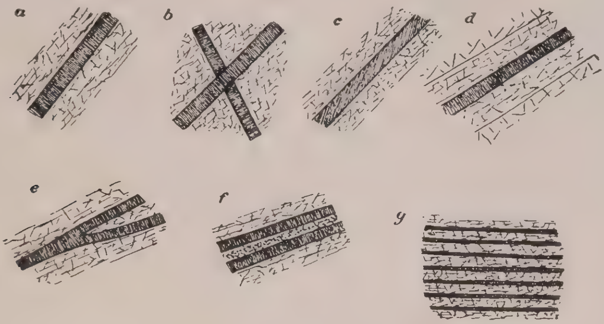


FIG. 3.—Typical asbestos veins.

(a) Regular vein.
(b) Crossing of veins.
(c) Drawn out vein in fault or slickenside.
(d) Seamy parting containing vein in middle.
(e) Forking of vein.
(f) Two veins divided by small seam of chrome iron ore, and serpentine.
(g) Ribbon-like arrangement of small veins.

horizontal direction, and when found in a knoll, can be traced across from one side of the hill to the other, nearly on the same plane; but as a rule the veins are irregularly placed.

The thickness of the veins varies from mere threads up to several inches; but it may be said that the largest bulk of the asbestos quarried is between $\frac{1}{4}''$ and $\frac{1}{2}''$ in length. The longer fibre is very often divided in the middle by a seam of serpentine carrying magnetic, or chrome iron ore. As a rule, in most of the mines, the asbestos can be easily separated from the rock; but in some veins the fibre appears to be 'frozen' to the rock, hence its complete separation is very difficult.

Most of the asbestos veins possessing commercial qualities are embedded in seamy partings of the serpentine measuring from 4″ to 6″ wide; the veins running, as a rule, parallel to the selvage planes. This is a characteristic feature of the Black Lake and Thetford district, to be found nowhere else. When freshly mined, these seamy partings—which separate with ease from the adjacent serpentine—can hardly be detected; but when exposed for some time to atmospheric action, they tarnish bluish-white, and can be readily distinguished from the surrounding rock. The cause of this peculiar colour is not well established: an effort to analyse these finely coloured films was not successful. It seems probable, however, that the serpentine of the seamy partings, which is an almost complete alteration of the original olivine rock, disintegrates more easily when exposed to atmospheric action than the other serpentine rock, and, as a result of this disintegration, a fine film of magnesite is formed on the

surface. These tarnished, seamy partings can be well recognized in the older quarries; and in some of them—like in quarry No. 8 of the old 'Union' mine, now of the 'Black Lake Consolidated'—a regular network of these 'partings' or 'veinholders' may be seen.

An analysis of chrysotile-asbestos, and of the seamy partings in which it was embedded, gave the following percentage composition:—

Chemical Symbols.	Asbestos.	Serpentine.
SiO_2	39·60	39·20
Al_2O_3	None	0·99
Fe_2O_3	2·58	2·97
FeO	1·62	4·02
MgO	41·99	44·02
H_2O	14·44	8·85

The question of the width of the asbestos veins in the Canadian asbestos district is one of great importance, since the value of a mine, or the profits of the same—all other considerations being equal—depend to a great extent upon this quality. As a general rule, wide veins that are ¾″ and over in length, deliver spinning fibre of an excellent quality, which commands the highest prices and finds a ready market; often even in times of depression, or over production. The short varieties, however, which constitute the bulk of the production, and are the backbone of all the enterprises, are less valuable; for in times of general business depression the effect is seriously felt, in the over-stocking of the market, and consequent drop in prices. On the other hand it must be said that, the width or thickness of a vein, *in situ*, is no criterion of the length of the fibre: and in many cases it is very difficult to distinguish the length by the naked eye because it often happens that the fine fibres are separated at right angles by fine films of serpentine; or sometimes by minute bands of serpentine charged with chrome iron ore, or magnetite; and sometimes even without any perceptible layer of rock: the only indication of this being an irregular, scarcely visible line, readily detected by the expert. In several places the serpentine contains iron ore disseminated in fine minute particles; while the associated asbestos fibre contains the same iron not in an undisseminated condition; but usually concentrated towards the middle of the vein.

The veins are sometimes displaced by the action of faults and slickensides in the serpentine: giving the impression that the fibre is of considerable length; whereas when closely examined it is found that they carry fibre of the usual length, but drawn out along the fissures. Sometimes a long woody fibre can be observed, deposited in a fissure between two rock portions. This woody material—usually termed hornblende by the miner—is in reality a picrolite, and is found principally in the mines at Thetford and East Broughton.

A peculiar occurrence of asbestos is noticed in the Megantic mine at Coleraine. Here the serpentine for several feet is laced with small, minute veins of asbestos $\frac{1}{16}$″ to ¼″ in thickness, exhibiting thus, a ribbon-like structure.

This same mode of occurrence can also be noticed in some quarries at Black Lake, and in one occurrence near Richmond: lot 6, range XV, Cleveland.

In the underground works of the Bell Asbestos Company, a unique opportunity is afforded for studying the occurrence of asbestos veins in general. In the writer's opinion, there is no place in southern Quebec where there is such a heterogeneous mass of asbestos veins exposed: and offering such great facilities for observation. It would be beyond the scope of this treatise, and would serve no useful purpose to enter here into a detailed, general description of these asbestos veins. A few points of technical interest, however, have been brought to light from this system of tunnelling and drifting. While the majority of the veins exposed seem to be concentrated in most irregular fashion—as described above—to limited portions of the serpentine, forming so to speak regular pay chutes, available for exploitation; in some of the accumulations it seemed as if the formation of the fissures and subsequent deposition of the asbestos had been going on with a certain regularity. Thus, in the easterly part of the underground works a cross-cut was noticed, where some fifteen veins, measuring all the way from $\frac{1}{4}''$ to $3''$ thick, were all parallel to each other, the veins dipping at an angle of 40°, and the spaces between them being from $6''$ to $15''$ wide. The most peculiar feature, however, was the intersection of these parallel veins by a second system of veins running almost perpendicular to the former. From the arrangement of the fibre at the points of intersection in both systems, the writer concluded that the veins in the second system were younger than those in the first; and since this is a very important point in connexion with the original deposition of the fibre, this observation will be dealt with further in the chapter on the Origin of Asbestos. As far as experience has shown, 'vein' fibre always contains the 'chrysotile' variety; whereas the hornblendic or amphibole variety has not been found in veins, but always in a drawn out condition, in fissures, or along fracture planes. The colour of the vein fibre freshly mined is white, sometimes of a creamy tint; but *in situ* it comprises all shades of green, from a very light-yellow green, as in the mines and outcrops east of the Thetford mines, in the township of Thetford, to a dark green-blue shade in the Thetford-Black Lake quarries.

The principal quality of the Canadian vein fibre is its great flexibility and silkiness, and it may be affirmed that, as far as the writer can judge, by a comparative study of fibres from many parts of the globe, there is not one instance where the fibre approaches the Canadian—especially that from Thetford—in its silkiness and delicacy of structure. There are deposits outside Canada which, at first sight, seem to equal the Canadian variety: as regards the length and the beautiful pearly, wavy shades; but immediately the single fibres are separated by the fingers, the harsh, glassy, and sometimes brittle qualities become at once apparent; they do not spin to perfection; the necessary flexibility is wanting, and, as a general rule, only a small percentage of the fibre can be used for spinning. As to the acid resisting qualities of Canadian chrysotile, compared with the hornblende varieties, the reader is referred to page 30, where full information on that subject is given.

The second variety of Canadian chrysotile, the so-called '*slip fibre*,' occurs, as a general rule, in the serpentine formation, in slickensided fault planes, caused by the moving or slipping of one rock portion along its contact with another portion. The fibre, so produced, is bedded on the fracture or slipping plane in a flat position, hence the name 'slip' fibre. The relation between 'vein' and 'slip' fibre seems to be plainly established, and as a general rule both varieties when separated from the rock, and worked out into mill fibre, present very few differences as far as length and quality are concerned. When freshly mined, the slip fibre exhibits many peculiarities. On sight, its drawn out condition—the overlapping of the single, fine threads—would lead to the inference that, the fibre is longer than the general run of vein fibre; but upon closer examination this is seen not to be the case. When subjected to microscopical examination, it is perceived that the fibres, although closely adhering to each other, terminate at a certain length, and that the apparent continuation of the same thread is in reality another fibre underlying the former. In most cases, however, an abrupt termination of a group of fibres overlying another group can be clearly noticed. While the fibres are, almost invariably, arranged throughout the fissured serpentine in every direction; but on the same fracture plane—no matter how small—a definite parallelism of the threads may be observed; and while this is immaterial as far as the ultimate percentage of extraction is concerned, it presents an important point in the discussion of the origin—which will be treated in a subsequent chapter. As a general rule the fibres over a certain plane are drawn out, and as noted above, all in the same direction, and in such a manner that, the whole surface appears to be coated with asbestos; while in some cases this coating takes the shape of a film, in others it is ⅛″, sometimes ⅜″ thick. A few cases have actually come under the notice of the writer where little grooves and hollows in the rock —several inches square—were filled with fibre ½″ and ¾″ wide, all arranged in the same direction, and in the plane of fraction. It frequently happens that two asbestos coated rock surfaces meet under a pointed or almost right angle. In these cases an accumulation of asbestos fibre in the form of rich bunches will be noticed; the fibres in most cases being arranged in most irregular fashion. The slip fibre is frequently intermixed with picrolite—the other form of fibrous serpentine; and although its outward appearance is similar to that of the real chrysotile fibre, its physical qualities, i.e., harshness and brittleness, are such as to exclude it from the uses to which the good fibre is applied. But inasmuch as it is difficult for the miner to discriminate in the pit between good and bad fibre, a considerable quantity of the picrolite found in association with good fibre goes to the mill for treatment, and in this way a certain percentage of the material is always mixed with the mill fibre. The colour of the slip fibre varies a great deal. Freshly mined, and separated by the fingers, the fibre has generally a beautiful white colour; whereas *in situ* it is light green, cream, or even deep white. Fibre near the surface is, as a general rule, discoloured, and has a brownish tint.

Ribbon structure of chrysotile-asbestos.

The occurrence of the 'slip' fibre variety is confined to that part of the serpentine belt stretching from range III, Broughton, to lot 17, range IV, Thetford, a distance of fourteen miles.

Discoloration and Alteration of Fibre.

Discoloration of the asbestos, and alteration of the fibre itself, can be observed everywhere throughout the region. This is due to three causes: (1) to atmospheric influences, and action of water; (2) to large forest fires, which swept over the region, and (3) to the presence of intrusive dikes.

A change of colour is very often observed on the surface, especially where the rock is shattered by intrusive dikes or some other causes: permitting water, generally charged with oxide of iron, to filtrate through the rock along lines of fracture, and to discolour the fibre. A discoloration, and to some extent a harshness of the fibre, is observed on the outcropping of deposits which have been swept by large bush fires. But we also find, sometimes, harsh fibre and brittle fibres at depth; and this condition may in a large measure be attributed either to the action of water or to the presence of intrusive dikes. In one mine in the township of Coleraine—now out of operation—the fibre occurs in seamy partings of pyroxene, the latter from 3″ to 6″ wide, cetting through the serpentine in irregular fashion. The pyroxene allows, through the many fissures it contains, the circulation of water, charged apparently with slight quantities of oxide of iron, and as a consequence much of the fibre is of a brownish tint: a condition not appreciated by the miner. This was observed down to a depth of 50 feet, and seemed still continuous towards depth.

As to the discoloration and alteration of the fibre through the presence of intrusive dikes, it must be stated that, as noted elsewhere, dissipation of water from the fibre causes brittleness and harshness, and it appears that the heated intrusive magma of the dike has had the same influence upon the asbestos veins as the forest fires have had on the surface outcroppings, namely, in dissipating some of the water contained in the fibre, thus destroying its silkiness and fine texture, and rendering it brittle and harsh. This condition, however, was not observed in every case where there is a granulite dike: in many instances no such alteration has taken place, and the fibre occurs in its normal condition.

A discoloration of the fibre—to such an extent as to affect seriously its sale—such as we sometimes see in foreign countries, has not been discovered in the Canadian asbestos region. A strong discoloration is a serious handicap. At one time the opinion prevailed that asbestos from any country—if it were of the chrysotile variety, and regardless of its outward colour—was a sufficient guarantee to the manufacturer that it contained all qualities essential for its successful commercial application; but experience has changed all this: off-coloured asbestos is economically comparable with off-coloured gems; advanced oxidation and iron lessen its utility.

Metallic Minerals Associated with Canadian Chrysotile-Asbestos.

There are only two metallic minerals occasionally associated with asbestos: magnetite and chromite. Both are sometimes found, as fine specks and grains,

accompanying the asbestos veins, and often constituting the partings which divide the veins into two stringers. These are admixtures, however, not at all welcomed by the miner; since they involve extra cobbing of the fibre by special apparatus, to separate the latter from these impurities. Chromite is often found in pockety deposits in the middle of the productive serpentine; but, hitherto, has never been found associated with the latter in such quantities as to be profitably mined.

An interesting feature in connexion with the occurrence of asbestos has been noticed in the lower pit of the Megantic quarry, on one of the serpentine hills, 1½ miles west of Coleraine station: here, mica of the muscovite variety, in small plates, occurs in considerable quantity in direct contact with the asbestos fibre—a feature observed nowhere else.

PRODUCTIVE SERPENTINE RANGE.

Broughton Serpentine.

The asbestos range proper commences in the northwesterly part of the third range of Broughton, about 2½ miles west from Tring Junction. (See map attached hereto.) Although there are a few small serpentine knolls scattered over ranges I and II; in none of them has asbestos of sufficient length and quantity been found. No development work has been done on any of the serpentine occurrences, and the writer is safe in stating that the outlook for the discovery of economic deposits is not encouraging. The rock encountered in ranges I and II consists principally of highly siliceous, schistose, fine-grained, greenish or greyish white rocks, changing from a gabbro to granitic and gneissic varieties. Their general strike varies between a north-south and northeast, dipping to the west and north; in fact, no regular uniform strike and dip is noticeable until near the westerly part of range III. Here, most of the rocks consist of the regular, greenish, Cambrian schists, of a strike north-south, with a dip of 50° to the west: here and there penetrated by small patches of serpentine. On lot 13 of the same range, the latter are more conspicuous than elsewhere. The serpentine commences about 300 feet from the main road, between lots 12 and 13, and continues to outcrop down the slope of the mountain at intervals, having a width of 500 feet. The outcrops all show a highly decomposed, soft, brownish serpentine, emerging in one or two places into a talcose rock of unctuous feel. The mountainous slope is heavily covered with humus, and for this reason the exact width of the serpentine belt could not be measured. In one place, at a distance of about 800 feet from the main road, close to the concession line, the highly schistose and crushed serpentine is productive of slip fibre of good quality. It appears that the serpentine, although of considerable width, is interrupted by tracts of Cambrian schists, cetting through the formation in a northeasterly sense.

The next outcrops of the serpentine belt to the northwest we find on the adjacent lot No. 13, range IV. Although the gently rising mountain side is heavily covered with bushes, several small outcrops could be perceived, indicating the continuation of the belt; and towards the middle of the property, at

a distance of 400 feet from the main road, a number of large outcrops and pits in solid serpentine, called the 'Miller' mine, are productive of slip fibre. The serpentine, as can be seen in the big pit, consists of parallel layers of a solid rock with a strike northeast 50°, and with a dip of 45° to the north. The bedding of this serpentine is generally well marked by large parallel joint planes. Between these are minor stratification lines, indicating cross bedding, which often depart as much as 40° and 50° from parallelism with the principal and true bedding plane. It is evident that these bedding planes have been caused by the sudden cooling of the serpentine magma; but it is also evident that no subsequent internal shifting, displacement, or faulting took place. There are lines of lamination in the mass which curve and bend about in an intricate manner, and which are due to secondary causes; these must be discriminated from the original bedding or deposition planes. The belt is here at least 150 feet wide, as a small pit in serpentine 140 feet south of the pit above referred to is entirely in a schistose, light-green serpentine. The accompanying country rock consists of the usual greenish schists, striking northeast, with a steep dip to the south.

The southwesterly extension of the belt can be traced in the westerly part of lot 13 on lot 13c. The mountain slope is here heavily covered with dense bushes for several thousand feet in the direction of the belt; and with the exception of one small outcrop, no further trace of the latter could be observed until we arrived at a distance of about 1,000 feet from the fourth concession line, where we found three pits recently made in a highly fissured schistose serpentine, highly charged with a beautiful white slip fibre, sometimes of an unctuous feel and aspect. All efforts to determine the width of the belt were in vain, for the humus is very heavy, while the bushes considerably impede any progress. Small boulders of serpentine containing small, but good, slip fibre were found strewn over the westerly part in the direction of the belt; and while this is of minor importance, it is nevertheless indicative of the probabilities of that district[1].

Farther to the southwest, on lot 13, range V, not far from the concession line, in a pit worked by the Boston Asbestos Company, the belt outcrops again, and is productive of excellent slip fibre. This belt exhibits features of an economic character observed nowhere else in the district, except on lot 2, range V, Thetford. The highly fissured, but otherwise comparatively solid serpentine, is heavily charged with a beautiful, white asbestos fibre rarely seen in the district. The serpentine here may be truly called 'fibrous'; and while not all the fibre produced from this pit possesses the requisite commercial qualities—especially as regards tensile strength—this apparent disadvantage is more than counterbalanced by the large extraction. The southerly boundary of the belt is constituted of green, and black striped slates and shales, also by green and grey slates, dipping under an angle of 65° to the south. Their strike is regular throughout, and the succession of the strata is tolerably uniform. To the

[1] Since writing the above, several outcrops of asbestos serpentine have been located in the westerly corner of the lot, and this evidently shows that the productive belt outcrops at intervals in lense-shaped bodies; since no continuation of the above occurrence could be established on the northerly part of lot 13, range V.

north most of the adjacent country rock is occupied by dark quartz, striped slate, and shales, underlain by green and grey slates, cut through by quartz veins; while the serpentine towards the northerly boundary is less fissured and has a more solid, compact character; exhibiting, however, in several places, a good, commercial quality of asbestos. The width of the productive belt between walls is 185 feet; but judging from present indications it is likely that small detached lense-shaped bodies of serpentine accompanying the main belt will be found in the northerly part of the lot.

Proceeding farther to the southwest, we find no outcrops of the serpentine until we reach the pits of the Boston Asbestos Company, on the westerly part of lot 13; here, the southerly contact of the belt is well defined, and can be followed for almost 1,000 feet. Its dip is steep to the south, and its strike varies a little in different parts of the property; from northeast 55° in the extreme east, to northeast 70° in the centre, and to northeast 62° to the west; continuing right into the property of the Frontenac asbestos property in the east half of lot 13, range VI. Several pits opened along the line of contact, show the serpentine occurring in a highly shattered and schistose dry condition, different from any of the productive serpentines in the district. In one of the pits a bed of dark, slippery soapstone occurs in a width of from 3 to 8 feet; which, when freshly mined, is hard and compact; but when exposed to atmospheric action, becomes tarnished, and disintegrates into a coarse clayey powder. This substance appears to be a decomposition product: its unctuous feel suggesting the loss of silica and a consequent preponderance of magnesia. It apparently contains also dolomite and some actinolite, and crystals of magnetite have been found in it. Its presence, however, in the serpentine is very annoying to the miner, as its slippery, soft condition renders work in the pit very dangerous. Besides, no reasonable depth can be obtained in a comparatively small quarry, on account of frequent cave-ins, which generally occur without any warning.

Irregular, gashy veins and stringers of a pure white, ferruginous dolomite intersect this blue talc and the serpentine, and their presence must be pronounced purely accidental since they have seldom been met with in other parts of the serpentine belt. What connexion these two minerals have with the serpentine is not well established; it suffices, however, to state that, slip fibre of good quality has been found in serpentine close to this talc; but further investigations towards depth have not been made.

The southerly contact of the belt consists of greenish, chloritic and micaceous schists, with a steep dip to the south; while the northerly contact is not well defined, and changes its contour within small intervals, and dioritic intrusions are noticed cutting the chloritic schists at right angles to the north.

The southwesterly continuation of the serpentine belt is concealed for about half a mile until we reach the large outcrops on the property of the Frontenac Asbestos Company, east half of lot 13, range IV. Here the serpentine outcrops on several places: some of them not strictly in the direction of the belt, but it is surmised that all the outcrops distributed over a width of 500 feet

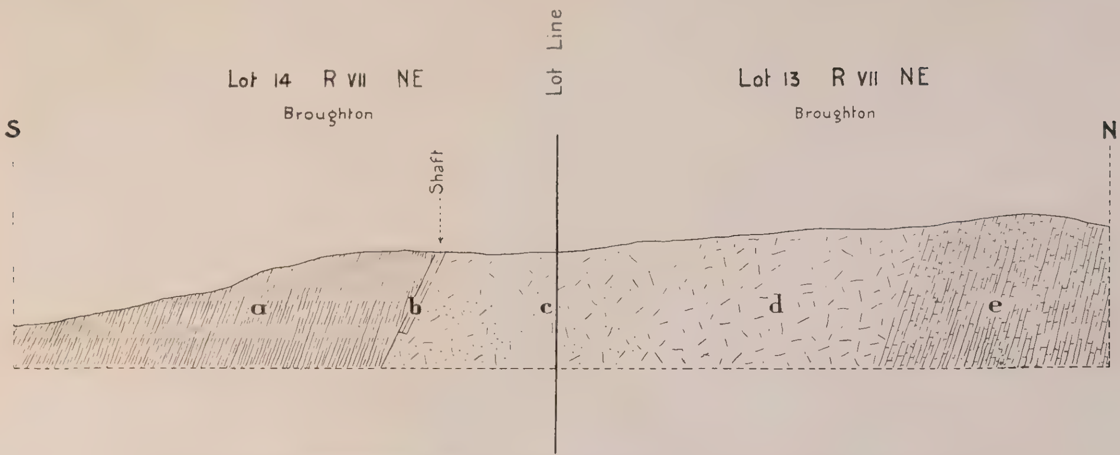


FIG. 4.—Section through northeast parts of lots 13 and 14, range VII, Broughton. (Scale, 1 inch to 150 feet.)

(a) Greenish schist and slate.
(b) Soapstone.
(c) Serpentine with "slip" fibre asbestos.
(d) Serpentine not productive.
(e) Quartzose slate.

emanate from the same source. The main belt, however, seems to be confined to a stretch of serpentine in the northerly part of the property, its width is here 132 feet, and it has been traced entirely on this lot for a length of 2,300 feet. The contact of this main belt to the south is well defined: its strike towards the Boston quarry—beginning from the Frontenac quarries, is northwest 68°; and towards the Quebec quarry to the west northeast 60°; it maintains all through a dip of 65° to the south. The rocks constituting the main part of the formation are grey, siliceous, and mica schists, and green and black striped schists, together with some conglomerates, greenish, chloritic shales, sometimes dark coloured and highly schistose, having a great quantity of quartz in irregular veins. They are generally much twisted and banded, but all possess a high dip. The serpentine of the main belt below the surface is of a compact, solid character: numerous fissures intersect the main mass in every direction, and these contain a greyish asbestos fibre of the 'slip' variety. There seems to be a gradual improvement of the quality and quantity of the fibre when approaching the southerly contact.

The main serpentine belt of the 'Frontenac' extends straight into the adjoining property, owned by the Ling Asbestos Company. At a distance of 560 feet from the main village road the serpentine belt has been explored and opened to a considerable extent by the above Company. Its southerly contact with the slate and schist formation is well defined: having a strike northeast 50°, with a dip to the south 65°. The northerly contact, however, as far as could be ascertained, exhibits sinuosities, produced by the varying strike at short intervals of the country rock. The latter, both to the south and to the north, is composed of similar rocks to those observed on the 'Frontenac' property, but their position relative to each other could not be made out owing to the heavy overburden. The serpentine on this property, which has now produced for a number of years a large tonnage of excellent asbestos fibre, presents here some noteworthy features; and since the latter is characteristic of the whole region, a detailed description may be advisable. The serpentine presents a light green rock, highly fissured, and at places schistose; slickensides as the result of thrust movements are frequent, and, as a rule, present highly polished surfaces. The dip of the cleavage in the serpentine is to the southeast, conforming with that of the greyish schistose altered slates which enclose the productive rock. A very light green material—a variety of 'picrolite' in a drawn out condition, and having the structure of wood—is often met with along the cracks and thrust planes; while a fibrous picrolite forms in many cases a thick coating of the latter, or fills fine interstices in the serpentine. A uniform distribution of the asbestos slip fibre is nowhere observed; at intervals, however, chutes of serpentine without any regular arrangement and highly charged with fibre, occur. These chutes may have the form of big lenses—from 5 to 15 feet larger axis—or they may form small pockets. Again, they are met with as enriched zones along a fracture plane of slickenside. This peculiar deposition of the richer asbestos rock does not mean that the lean portions of the serpentine contain no fibre at all; on the contrary, it has been found that the whole lean mass is

fibrous to a more or less extent, and that no mistake is being made in sending all the serpentine through the mill. Apart from the occurrence of slip fibre some small veins of asbestos are occasionally met with; and while the fibre in these veins show in almost all cases more or less the effects of pressure or thrust movement of the rocks, it is nevertheless of a fine, silky quality; its only difference from the Thetford fibre being its grass-green colour, when *in situ*. As a general rule, a gradual enrichment of the asbestos chutes is observed towards the contacts with the country rock; and this is specially noticeable along the southerly contact line where a greater preponderance of fissured serpentine has been observed than elsewhere.

Although the serpentine is, generally, highly fissured, foliated, and schistose, allowing a free circulation of surface water, some parts are met with which are very compact and massive, and give, indeed, as much trouble in their forced disintegration as any hard portions in the Thetford serpentine.

The serpentine is more or less impure; owing to the presence of other minerals which are mixed with it. Among these may be mentioned the remains of the magnesia silicates, from which it has been formed, namely, olivine, pyroxene, and hornblende. Metallic looking specks, or crystals of ores are common: i.e., magnetic and chromite. Talc or soapstone has been found occasionally as a solid rock or as bluish soft decomposed material, resembling clay, the latter in narrow fissures.

Proceeding farther west the serpentine belt widens out considerably; and on the next property worked by the 'Eastern Townships Asbestos Company,' towards the road between ranges VI, and VII, its approximate width as measured in the road is 900 feet. Both the southerly and northerly contacts are covered with a heavy overburden; but outcrops of serpentine and country rock at intervals indicate that the strike of the former is approximately northeast 15°. This contact enters lot 14, range VII, close to its northeasterly corner, and makes then a sharp turn to the southwest. The northerly contact forms almost a straight line from the 'Quebec' mine to the concession road VI-VII, and has a strike northeast 50°. The main exploration and development work has been done at a distance of 75 feet from the northerly contact, in a series of pits arranged in a parallel line to the latter. No special features were noted in this serpentine, other than those already described as occurring at the 'Quebec' quarry, except, perhaps, that band-like soapstone deposits, set through the serpentine in irregular fashion, are of more frequent occurrence.[1]

Crossing the concession road VI-VII, we find on the next lot, No. 13, the greatest width of the Broughton serpentine belt; measured by a line running through the easterly corner in a straight east and west direction: the width of

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[1] Since writing the above the Company has opened a pit on the southeasterly contact close to the main road, this contact composed of the regular blackish slates, and observed and described in connexion with the 'Quebec' and 'Frontenac' mines, tips towards the east under an angle of 65° and appears to be well defined. Beautiful crude 'vein fibre' asbestos ¾" wide has been found all along the contact and it is expected that quite a quantity of this quality will be encountered, judging from results of the development work on the adjacent property, lot 14, range VII, in the 'Fraser' mine.

the belt here being about 1,000 feet. Farther towards the southwest it is again tapering down, and the southeasterly contact, which has a straight, southerly course in lot 13, range VI, makes a sharp turn, entering lot 14, range VII, and maintains for some distance a strike of northeast 60°. The contact here is well defined, dipping to the south under an angle of 65°; and consists of a soft talcose rock from 1 to 2 feet wide, accompanied by the usual greenish chloritic schists. Several strongly developed asbestos veins occur all along this contact; and by reason of their individual richness and silkiness of fibre, represent—from a mineralogical and geological point of view—the most conspicuous occurrence of asbestos fibre in the whole Broughton serpentine belt. The principal vein has been explored and worked downward by three inclined shafts, the deepest of which is reported to be 90 feet, with a system of drifts—the works being known under the name of 'Fraser' mine. It follows down conformably with the country rock within the range of the contact zone; but its habitus and behaviour are irregular: it splits up into narrow stringers, which again may coalesce and form a bigger vein for some distance, or may lose themselves in fine stringers through the serpentine. At some places this vein attains a thickness of several inches, and the fibre is then beautifully soft and silky. Proceeding from the contact towards the road and beyond in a northwesterly direction we find a strong development of 'slip' fibred serpentine; and judging from the various outcrops and prospecting pits the width of this productive fibred zone is at least 260 feet, which covers also a part of lot 13. Figure 4 shows an ideal section through the formation.

The continuation of the productive belt to the southwest is found in the quarries of the 'Broughton Asbestos Fibre Company,' which occupy an area located in the southwesterly corner of lot 13, range VII. Here, the southerly contact towards the slate and schist formation follows close to the southwesterly boundary line on lot 14, and presents the same outward features as observed at the 'Fraser' mine. The working quarries are all located along this contact; and, owing to the southerly dip of the latter—which varies between 55° and 65° to the south—the fibrous serpentine body increases with depth, occupying thus more and more ground of the property belonging to the 'Amalgamated Asbestos Corporation.' The general features of the productive serpentine area are about the same as those observed in the quarry of the 'Ling Asbestos Company.' It appears, however, that the 'vein' fibre variety is more strongly developed; the thickness of some of these veins sometimes reaching 1″ to 1½″, and a good percentage of 'crude' is occasionally obtained.

The serpentine shows also, numerous crushed veins along its cleavage and schistosity. The colour of the fibre *in situ* is a light green and white; but others are found which exhibit a fading amber colour; while some of the asbestos is dark coloured, coming from a dark coloured serpentine; however, all these varieties become white in colour when exposed to the light, and produce a fibre of good quality. In the upper part of the most westerly quarry a dark, soft, and clayey material appears in fissures between rock portions, in a thickness of from 3″ to 6″, which becomes quite hard when exposed to the air. This

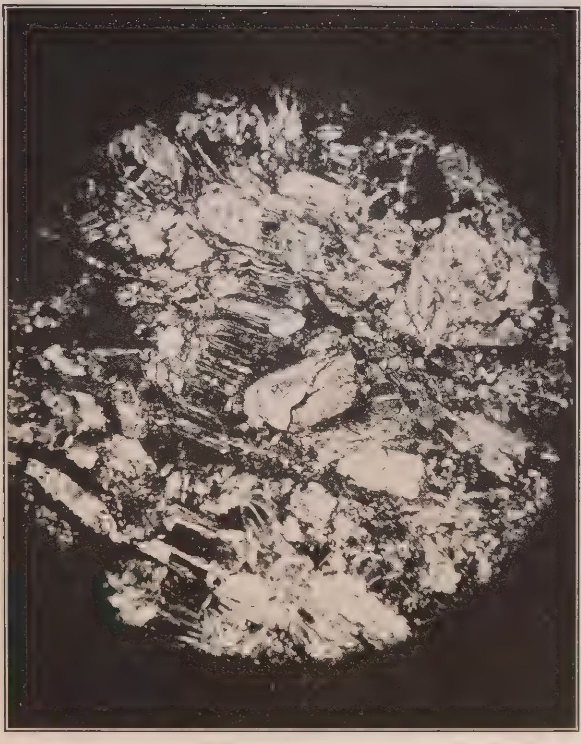
dark material is apparently a decomposition product of serpentine, mixed with fragmentary, disintegrated portions of soapstone.

The approximate boundary of the serpentine belt to the north takes an almost southerly course from the concession road VI-VII, down to the division line of lot 13, on range VII, thus reducing gradually the width of the belt, along the division line noted above, from over 1,000 feet to about 450 feet. Proceeding farther to the southwest, we find quite a number of natural outcrops, pits, and excavations on the Tanguay lot, which in a more or less degree indicate the position and continuation of the productive belt. The exploration work is confined to the southeasterly corner of the lot, and extends over an area measuring 1,300 feet long by 400 feet wide. A very noteworthy feature of this property is the occurrence of excellent vein fibre similar to the Black Lake asbestos, in a dark massive serpentine. This is the only deposit—known to the writer—along the Broughton belt, that shows some of the distinct features of the massive serpentine which is so productive of good vein fibre; but how far or how deep this condition in the otherwise much crushed and fissured rock extends must remain, at the present moment, a matter of conjecture, since the development work is of very limited extent. Some 400 feet farther west, the character of the serpentine changes: instead of the dark, massive rock, is found a highly coloured, schistose, and fissured serpentine, which, as far as the several small pits in that region indicate, is productive of picrolite of long woody fibre and ligniform serpentine. This long fibred, exceedingly smooth and elastic material has, it appears, found no regular commercial application, as yet; but it is likely that some day appropriate use will be found for it in the arts. Proceeding still farther west on this property, we find an extensive development of slip fibre rock: the serpentine appears massive, and hard, though highly fissured and saturated with a silky fibre, and much resembles the variety met with on the Ling property. As to both the northerly and southerly contacts of the belt, they are concealed under the heavy drift; no protruding rocks of any kind can be noticed, but the writer has reason to believe that both these contacts run approximately parallel to the division line of lots 13 and 14, in the manner indicated on the accompanying map. Proceeding farther southwest, on lot 13, range VII, and its immediate vicinity to the north and south, we find a heavy overburden covered with bushes, but no outcrops of any kind can be perceived that give a clue to the position of the underlying rocks. Along the concession road VII-VIII, a succession of greenish schists and slates was observed, but no serpentine. The first outcrops of the latter are to be seen on lot 13, range VIII, about 1,500 feet in from the concession road in a little gully 100 feet wide, which traverses the property in an east-west direction. Here, the southerly contact of the belt can be noticed in several places, and proceeding farther about 1,000 feet along the middle line of the property we come to several outcrops of serpentine, exhibiting fibrous rock of productive quality. The accompanying green schists and slate of the southerly contact dip 65° to the south; their strike is northeast 55°, and the width of the productive serpentine about 125 feet. The next outcrops of serpentine are found in the extreme westerly portion in the property

to the north of the east-west division line. Here, over an area 500 feet long by 110 feet wide, eight outcrops show the existence of a fibrous serpentine belt, producing material similar to that mined elsewhere in the district. Although highly fibrous and fissured the serpentine is compact and quite solid, and when freshly mined presents a yellowish greenish colour. Some of the fibre extracted exhibits great silkiness and elasticity, and the very small amount of discoloured fibre on the surface—generally brought about by atmospheric action—is surprising. No contact with the adjacent schist formation could be noticed anywhere; but along the concession road VIII-IX, and on lot No. 13, in range IX, a number of widely separated serpentine outcrops indicate that the serpentine belt on lot 13, range VIII, must become wider as we proceed in westerly direction; although the northerly contact seems to retain its straight line and follow the east-westerly division line of the lot. Thus on lot 13, range IX, the width of the belt is found to be at least several hundred feet; but frequently interrupted by bands of country rock, parallel to the contacts. Owing to the heavy overburden, the exact position of the productive belt could not be determined; but there is every reason to believe that it crosses the concession road in its full width into the lot last mentioned: deduced from the fact that some of the best looking outcrops of fibrous serpentine are found on the roadside. The northerly contact of the serpentine belt takes a straight westerly turn, beginning from the concession road, and traversing the line between lots 12 and 13, at a distance of 1,500 feet from the road. This contact follows approximately the northerly fringe of a little gully, from 50 to 75 feet wide; it is, however, entirely lost sight of on lot 12. The serpentine on this lot, and along the gully above noted, is concealed from view by the heavy drift material; but a few outcrops and pits close to the division line of lots 12 and 13 exhibit its excellent productive quality. The serpentine appears to be highly schistose, fractured, and full of fine fissures filled with a white, soft, and silky asbestos slip fibre. When freshly mined the material has a white, chalky appearance, an unctuous feel, and the fibre seems to run through the rock in every conceivable direction.

Proceeding farther to the west on lots 12 and 13, no further outcrops are noticeable which could assist in locating the serpentine belt; only a few serpentinized rocks, quartzites, and gabbros can be seen, but no true serpentine appears until we arrive at the northeasterly part of lot 13, range X. Here, a steep, hilly range crosses this and the adjoining properties in a northerly direction, and several small prospecting pits which have been put down in the vicinity of the east-westerly division line in the overlying heavy humus exhibited a dark green, dry looking, brittle serpentine of great schistosity. Occasionally, fine asbestos slip fibre may be seen in the fractural interstices, assuming, at places, such an extent as to be of economic value. The width of the serpentine belt so far established is 250 feet, but it is still continuous towards the north and south, under the heavy overburden. It is reported that serpentine also occurs on lot 12, on the same mountain range; but a careful search failed to discover any outcrops or pits.

The next outcrop of serpentine to the west occurs on lot 14, range XI, near the east-west middle line, and about 750 feet from the main road. Judging



Microphotograph of a peculiar species of serpentine, from lot 13, range 11, Broughton. Magnified 20 diameters. For description see page 63.

from the colour, and the general aspect, this serpentine seems to have passed through a number of alteration stages; and while the asbestiform matter arranged in veins resembles, at first sight, the 'Thetford' occurrence, upon closer examination it is found to contain a soft, white material of silky lustre, with ligniform, brittle structure of no economic value. This mineral, which is of very rare occurrence, as well as the accompanying serpentine, has been analysed and gave the following results:—

——	Serpentine.	Asbestiform Mineral.	Authority.
SiO_2	41·15	44·83	Dr. Milton Hersey, Montreal.
Al_2O_3	13·21	2·36	
Fe_2O_3	2·52	7·35	
FeO	10·82	8·90	
CaO	16·78	19·05	
MgO	12·77	11·85	
H_2O	3·40	4·17	

In comparing this analysis with those of the normal species of serpentine asbestos, we find, that while the content of magnesia has been reduced from an average of 40 to an average of about 12 per cent, a new constituent has entered into the chemical composition, namely, lime, to the extent of from 16·78 to 19·05 per cent. The serpentine has not the ordinary characteristics so commonly found in the true species: it is of a pale grey colour, is soft, and when exposed to atmospheric action, tarnishes slightly; cracks and interstices are filled with calcite, and it appears as if this mineral is found in the rock wherever displacement or disturbances have taken place. The asbestiform mineral is composed of fine silky threads, arranged in parallel, columnar fashion, vertical to the boundary planes. On account of its large content of lime, the writer has given it the name 'Lime Asbestos.' (See page 32).

The writer submitted a slide of this peculiar serpentine to Dr. Alfred W. G. Wilson of the Mines Branch for examination, and his observations are as follows:—

> 'This slide contains a pyroxene associated with a much altered plagioclase feldspar. Pale green secondary serpentine is present in large amount. On looking over the analysis, I note the presence of a larger amount of Al_2O_3 and of CaO than is usually found in the serpentine. These two, in part at least, were probably associated in the original plagioclase feldspar. The rock is properly called a pyroxenite. In the field it undoubtedly resembles serpentine; in larger samples, no doubt, the pyroxene crystals could be distinguished. On weathered surfaces they would stand out as small rough points.'

The rocks observed in this region differ in character considerably from those observed all along the contact of the 'Broughton' serpentine belt, and the Pre-Cambrian character which was noticed there, seems to be entirely absent in the present area; these rocks consist of serpentinized, greyish quartzites, alternating with feldspathic, quartzose rocks, and with black slates, and chloritic rocks. Their

general strike is east and west; but they are occasionally cut by beds of greyish limestone, with a north-south strike, in which the original strike is always somewhat diverted.

No more outcrops of serpentine can be seen until close to the town line between the townships of Broughton and Thetford. That part of the country is covered with tilled ground, and with bushes, and for this reason exploration work is greatly handicapped. The contacts which formerly could be followed very closely disappear from view in ranges X and XI, in fact, much of the territory just considered is taken up by rocks above mentioned.

The last natural outcrops of serpentine in 'Broughton' township are probably located in the southwesterly corner of lot 12, range XI: they exhibit vein and slip fibre intermingled with each other.

The writer was unable to determine whether these outcrops were big boulders or not; but the exploration work now being carried on will determine their true character.

Thetford Serpentine

Proceeding farther southwest into the township of Thetford there is on lot 1, range V, quite a stretch of tilled ground; but no outcrops are visible. A careful search, however, over this property, in the presumed direction of the belt, resulted in the discovery of several excellent float specimens of vein asbestos and serpentine. The outcrops of serpentine were found towards the western boundary line of the lot, about 1,500 feet north from the main road, and near the farmers' outhouses. Here, a knoll of serpentine protrudes quite prominently above the flat rising ground, and in one place near the barn some 'slip' fibre was detected. Worthy of mention, also, was the finding of a big block of serpentine, containing a number of veins of asbestos $\frac{1}{4}''$, $\frac{5}{8}''$, and $\frac{7}{8}''$

FIG. 5.—Section through productive part of lot 2, range V, Thetford (Berlin Asbestos Co.). (Scale 1 inch to 50 feet.)

(a) Quartzose slate and quartzite.
(b) Highly fractured serpentine with "slip" fibre.
(c) Soapstone.
(d) Unproductive serpentine.
(e) Green and black slates, quartzitic rocks.

thick. The fibre is white and silky, and compares favourably with the o mined in Thetford and Black Lake; and, from present indications, it is qui evident that, this belt is several hundred feet wide. On the next lot, No. 2, the is even a greater development of the serpentine: as six pits made in the hea

soil by the 'Berlin Asbestos Company' have disclosed the existence of excellent 'slip' fibre rock, extending—so far as work at this moment has demonstrated—over a length of 450 feet, and a width of over 150 feet. The belt still continues in all four directions of the compass, under the heavy drift; and it is probable that it will prove to be quite an extensive, productive, asbestos deposit: further development will undoubtedly demonstrate this. The serpentine tapped by these pits is somewhat different from that generally met in the 'Broughton' district. While its schistosity, cleavage, and other general characteristics are about the same, its colour and fibrosity are different: freshly mined rock, when dried, is a cream-white colour. This is, perhaps, due to the presence of finely divided talc or soapstone, or, to a partial leaching out of the magnesia in the serpentine, caused by carbonic acid waters, and resulting in the formation of magnesite. The rock is highly fissured, filled with fine crevices and interstices; the latter forming, generally, the receptacle of the fibre. The highly fibrous nature of the rock is evidenced in a pronounced degree; and although picrolite and actinolite appear to be abundant throughout the rock, excellent mill and spinning fibre is also present.

Bands of a greyish-green, pure soapstone are frequently found in the serpentine and adjacent country rock: and judging from the quality of the surface samples, there is reason to believe that, some day, this mineral, if properly prepared, may find a ready sale.

On the west half of lot 2, range V, the continuation of the serpentine belt has been established through several pits; the bottom of the principal pit, which is about 12 feet deep, is in a highly schistose, dark green, fissured serpentine, which, on fractured surfaces, is covered with a thick film of asbestos 'slip' fibre.

On lot 3, range V, nothing can be seen in the way of serpentine *in situ;* but on lot 4, quite a quantity of float serpentine is found—in some instances carrying good asbestos fibre. In lot 4, towards the centre, a big boulder can be noticed, and which, by reason of its different composition from the underlying formation, must have been deposited here by glacial action. This boulder is composed of rock fragments, probably of a serpentine gabbro from 12″ to 2′–6″ thick, which are cemented together by pyroxenic rock matter.

Proceeding towards lot 5, we find here also the serpentine outcropping on the lower part of the slope of the hilly range. The quality in a pit only 25 feet long, by 8 feet wide, is of a dry, brittle, schistose character with some 'slip' fibre irregularly distributed throughout. Like conditions exist in a pit 125 feet farther west; the southern border of the serpentine in which is composed of a greenish, Cambrian schist, having a northeast strike and a dip of 42° south. The lower portion of the hill and a part of the lower flat appear to be also occupied by serpentine—judging from the numerous float fragments which are dug up in ploughing the field.

On lot 6, close to the mountainous range, many cross-cuts and pits demonstrate the existence of at least two serpentine bands. The lower one, in which a pit 20 × 30 feet, and several smaller ones have been made, has a width of 50 feet, which can be measured between quartzose Cambrian slates: the latter hav-

ing an east-westerly strike, with a dip of 60° south. The serpentine, which is of a dark green colour, is highly fissured: containing small veins of calcite, a ferruginous dolomite, and some asbestos fibre of the 'slip' variety. Higher up on the hill several pits have been opened up in soapstone; but whether this rock is directly associated with serpentine, or whether it forms band-like deposits similar to those on lot 2, of the same range, could not be determined with certainty; judging, however, from the sporadic occurrence of the mineral all over the mountainous range, it appears that its distribution is quite extensive.

Proceeding farther in a southwesterly direction, we find on lot 9, about 3,000 feet from the main road, and at the foot of the hilly range, outcrops of serpentine, which, by reason of their content of beautiful asbestos vein fibre, promise to rank in the future as producing quarries. While all the deposits so far described belong to the 'slip' fibre variety, this is the first one in the belt that exhibits almost exclusively the vein character, and it is safe to assume that the vein fibre belt commences with this deposit. This serpentine is 95 feet wide, has a strike northeast of 60°, and is bounded on both sides by Cambrian schists, similar to those observed in Broughton.

The serpentine outcrops on lot 10, close to the line in the direction of the belt, the productive length of the latter so far determined being 300 feet. From this point on, proceeding southwest, the serpentine disappears completely for about 30 acres under the heavy drift, reappearing again at lot 13, range V, where considerable work has been done in the westerly part of the property, on the slope of the hilly range. The belt has here a width of at least 275 feet, is opened through a number of prospecting trenches, all over a length of 600 feet, and vein fibre is found in almost all the pits—some of it not quite formed. In a rock cut 150 feet long, quite a quantity of slip fibre can be perceived, together with fine veins of asbestos. The serpentine is highly fissured, is of a light green colour; and slickensided surfaces—as the direct result of rock movements—are plentiful.

Outcrops of serpentine were reported to occur on lots 11, 12, and 13, range IV; but the writer was not able to locate any, except a number of big boulders which contained some excellent veins of fibre on lot 13.

No further trace of the belt can be found in the westerly part of range V; but on lots 16 and 17 serpentine outcrops again, in a width of 650 feet, not far from the range line IV-V. The Robertson Asbestos Company, owners of these properties, have expended considerable money in clearing and opening up the ground, with the result that, a productive area has been established measuring 1,100 feet long by 650 feet wide, and which is still continuous towards the northeast and southwest, under the heavy drift. The serpentine, although yet of a light greenish colour, approximates to the 'Thetford' variety in its content of asbestos veins. Parts of the rock seem to contain a dense network of veins, with greenish, highly silky, and elastic fibre. Close to the surface the rock is much shattered, and to some extent decomposed; but towards depth the serpentine becomes solid, yielding also a higher percentage of fibre. The southerly contact is composed of greenish, hard, Cambrian slate, occasionally intersected by quartz stringers, with a strike 62° northeast, having a dip of 48° south.

The serpentine seems to terminate west of these properties; for no outcrops have been noticed proceeding in a southwesterly direction until near to lot 23, ranges V and VI, where the great serpentine belt of Thetford and Black Lake commences.

There are several scattered occurrences of serpentine in the southerly part of Thetford township, but, being only of secondary importance, they will here only be briefly dealt with. Commencing with the most southerly occurrences on range X, a narrow serpentine belt of a varied character, beginning in the southerly part of lot 5, strikes through the country in a southwesterly direction—almost parallel with the range lines. On the lot just mentioned, the rock is not true serpentine; it is a greyish, soft lime serpentine, in which part of the magnesia has been replaced by lime, similar to the variety found on lot 14, range XI, Broughton, and further described on page 63. An adit in a knoll of serpentine shows a number of veins of a fibrous, silky, but brittle material. Slender prisms of quartz are frequently seen in association with the fibrous threads, and in some cases crystals from $\frac{1}{4}''$ to $1''$ diameter could be noticed. Serpentine rock of the variety just described was found as far as lot 10, (same range); but several openings made in agricultural land not far from the main road disclosed a dark serpentine on lots 6, 7, and 10—whether these were boulders or solid rock could not be determined.

Serpentine rock-masses bordered by diabase rocks are met with on the northeasterly border of Clapham lake, ranges VII, and IX, and on several lots in range VII; but so far most of the rocks found are of the harder unproductive variety, and the writer believes that it is improbable that asbestos in paying quantities will ever be discovered in that locality.

The Great Vein Fibre Belt.

The 'vein' fibre belt, on account of its magnitude, outstanding physical features, and economic characteristics, is the predominant source of the great Canadian asbestos industry; and, at the present time, of the asbestos commerce of the world. It was in this belt that the first asbestos of commercial quality was mined thirty years ago; it was here that the mining and refining of this material passed through the evolutionary stages of trial, experiment, and economic achievement: and all this on such a scale of magnitude, that the story forms an important chapter of industrial history. Moreover, the almost prodigal extent of these deposits, combined with their transcendant qualities, has not only given Canada the command of the markets of the world; but the origin and cause of this magnificent concentration of Nature's gift of asbestos has baffled scientists everywhere, and stimulated the search for the mineral all over the globe. The writer has examined samples sent to him for examination from Gowganda, and Chibougamau—both localities in Canada; California, Arizona, Casper mountains, and Wyoming—all in the United States; Philippine islands; Pilbarra district—Western Australia; India; Transvaal, and Griqualand—South Africa; Yeneseisk district—Siberia; Mongolia; Ural mountains; Italy; and

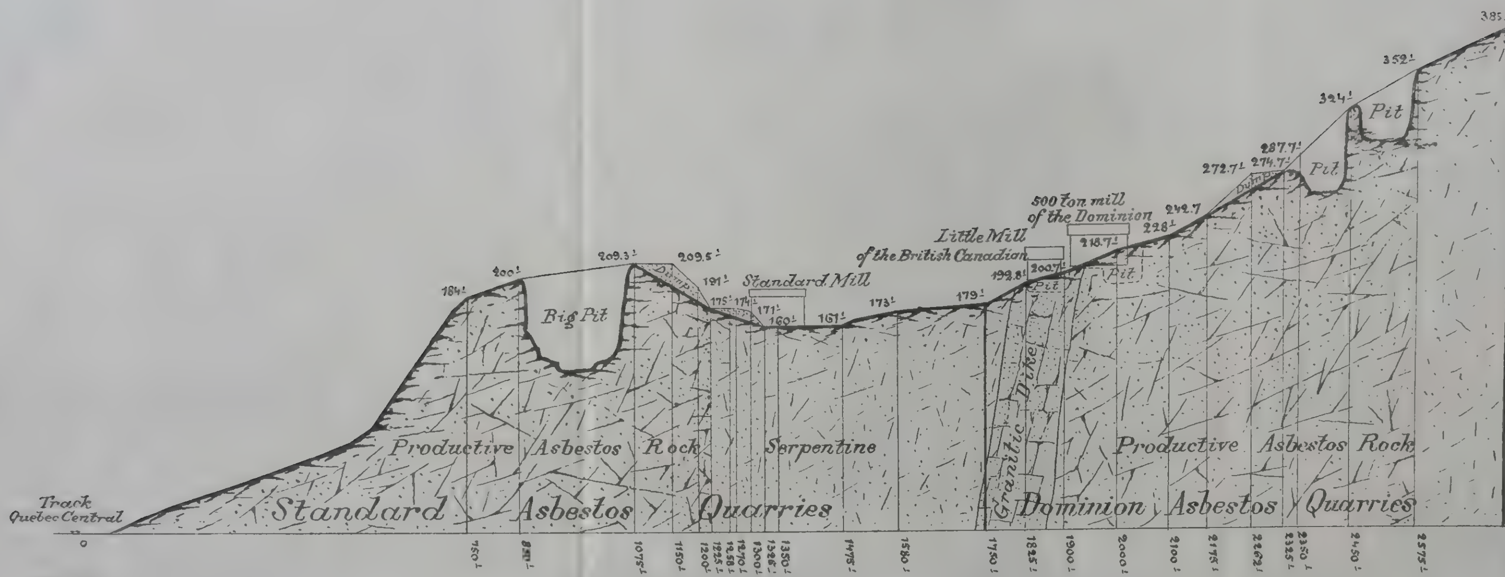
Austria; but he has yet to see asbestos fibre which equals, as regards its fine silky quality, and tensile strength, that produced in the Thetford-Black Lake district, in the Province of Quebec.

In giving a description of this 'vein' fibre belt it may be mentioned that, the writer has found unusual difficulty in delimiting the boundaries of the same, owing to the heavy drift material, and dense bushes which cover the surface. The contact lines of the serpentine and the country rock are mostly approximately conjectural; the prominent hill features, however, many of them caused through upheavals of the serpentine, having aided a great deal in their determination. The country between Thetford and Black Lake—a distance of about five miles—is mostly taken up by serpentine and allied rocks; although there are quite a number of granite hills intersecting the latter, and it has been deemed advisable not to make any distinction in the colours on the map, but simply to indicate the presence of the granite hills in certain spots.

The great 'fibre' belt commences in the southerly part of lot 23, in range V, of Thetford. Before an investigation of this productive belt was made, it was thought that all the outcrops of asbestos on lots 2, 6, 9, and 13 were located in one and the same continuous belt, which would also connect with the belt under consideration, but a diligent search has failed to locate any intermediate outcrops or connexions between lots 13 and 23. This barren stretch is taken up by quartzitic and feldspathic schist, flanked to the southeast by slates of various colours; purple, black, green, and grey; together with sandstones, quartziferous schists, and conglomerates.

The Northern Contact.—Following first, the northerly boundary of the belt, and beginning on lot 23, range V, Thetford, the contact takes a strict westerly course, crossing successively the railway tracks and the Thetford river on lots 24 and 25 (same range), and remaining on the right bank of the river probably as far as lot 26, range VIII, township of Ireland. On lot 23, an extensive development of greenish rocks, mostly composed of serpentine gabbros and a dark brittle non-productive serpentine can be noticed, and quite a number of small hills composed of these rocks have been worked to some extent in the search for asbestos; but without success. In the lower part of the same lot a light green serpentine was noticed, which carried small stringers of a silky asbestos. Many boulders of serpentine were encountered, which in a more or less degree exhibited asbestos stringers.

On lot 24, a very dark green serpentine is largely developed, but so far has not proved to be of any economic value. Crossing to the right bank of the river on lot 25, we find the country strewn with numerous boulders of quartzitic, feldspathic, dioritic character. No serpentine could be observed; but from the fact that the river exhibits in some places a greenish gabbro, in places serpentinized, it is fair to assume that the contact is not far from the course of the river, probably on the right bank of the latter. Some outcrops of unproductive serpentine were noticed on the bank of the river towards the town line Thetford-Ireland, and farther up the Ireland road, running between the concessions X and XI. A dump of fibrous serpentine was seen—the result of well digging—



7068—p. 68

Fig. 6. —Cut through the hill south of Black Lake station.

not far from the line between lots 24 and 25, in range IX. Nothing further regarding the extent of this serpentine formation can be said, but there seems to be good reason to believe that this outcrop forms the approximate northerly boundary of the belt; because, proceeding farther up (to the northwest) the Ireland road, we find no more traces of serpentine; dark greenish slates with numerous quartz stringers, felsites, and quartzitic schists take its place, their general strike being northeast 52°, with an almost vertical dip. Proceeding farther in a southwesterly direction, following approximately the course of the river, we find quite a number of serpentine boulders; but no serpentine *in situ*. If these numerous boulders can be taken as an indication, it is very probable that the northerly contact of the belt follows the course of the river, perhaps on the right side of the latter. Thick bushes and underbrush prevent an intelligent study of that part of the country until we reach a point about three-quarters of a mile east of Black Lake. A stretch of open country, here and there interrupted by patches of underbrush and bushes, begins and continues for about two miles. No actual contacts can be noted anywhere; but serpentine boulders are plentiful, and judging from serpentine outcrops on the gently rising slope to the south, it seems likely the contact follows along the left bank of the river. Some efforts have been made to mine asbestos close to the main road to Coleraine, not far from the village, but without any material success.

Proceeding still farther west, we find that while the northeasterly shore is taken up by sandy beaches covered with bushes, the southern shore has numerous serpentine exposures, which constitute the foothills of the great serpentine range to the south. Crossing the lake from the mouth of the Thetford river in a westerly direction, we find exposures of very dark green, hard serpentine, on the west shore for a stretch of about 150 feet; but owing to the heavy bushes covering the ground no further trace of the same can be found farther in. West of Black Lake the country is difficult of access, due to dense bushes, and the continuance of the northern fringe of the belt is indicated by the serpentine hill on lot 24, range III, of Ireland, where asbestos mining has been going on for several years; but owing to lack of transportation facilities, has been suspended. Proceeding farther west we have outcrops on lot 25, range I, and lot 24, range II, of Wolfestown. On the former, upon the banks of a creek, a large development of dark green, massive serpentine can be noticed, exhibiting small asbestos veins. On lot 24, a steep mountainous range is wholly composed of serpentine, and on the crest of the same several openings in serpentine—known as the 'Belmina' mines—disclose quite a number of asbestos veins.

The Southern Contact.—Beginning in the southeastern part of lot 23, range V, and proceeding westward, we have quite a number of hills which are composed wholly of serpentine, and one hill on lot 25, not far from the main road, forms quite an extensive promontory overlooking the whole valley of the Thetford river. With the exception, however, of these hilly ridges, no indication of serpentine *in situ* can be noticed; the country as far as the concession road between ranges VII and VIII, being very heavily covered with drift material and bushes. Ascending up the gently rising slope on the road between lots 25

and 26, we perceived a great number of boulders, and these increased in number as we proceeded, especially on lots 25 and 26. They are composed mostly of serpentine, some of them with small asbestos veins; and it is reported that recently a shaft was sunk on lot 26, in which asbestos veins were encountered. From the meagre outcrops of country rock observed above the higher concession road it appears that quartzitic felsitic schists with granitic, dioritic dikes, flank the southeasterly portion of the great serpentine belt; their strike generally conforms approximately to the supposed and concealed contact of the serpentine belt, namely northeast 20°; but on the hilly road on range VIII, leading to the summit of the mountain, the strike changes to north-south with a dip to the west. Crossing the town and county line in range VIII, we have quite an extensive development of serpentine on lots 18 and 19, range C of Coleraine; this serpentine is of the non-productive variety, and some work done on the same many years ago has failed to produce any results. It is flanked to the east by dioritic and felsitic rocks, sometimes emerging into a pure quartzite, and forming prominent tall features in the landscape of the surrounding country.

The next large outcrop of serpentine is found on lots 16 and 17, range A, Coleraine. Here, extensive quarry work has been done by the Canadian Chrome Company, over several acres of ground, with the result that, workable deposits of chrome iron ore have been located and worked for a number of years. The serpentine encountered here is somewhat different from that met with along the northern contact, since it is of a light green colour, much more brittle, hard, and highly fissured and slickensided as the results of great rock movements. No more outcrops of serpentine were seen to the south of those just mentioned. The surrounding country is heavily drift-covered, and dense bushes—especially to the south—are frequent. In the accompanying map sheet the supposed contact is put down between lots 15 and 16, but the writer is not at all sure whether the limits should not be extended farther south. The next largest outcrops of serpentine forming prominent hill features are encountered on lots 19 and 20, range A, as far as lot 23, east of the Poudrier road; and it is safe to say that these hills constitute the western wing of the tongue-shaped serpentine belt in the eastern part of Coleraine. In the western part of lot 23, range A, a considerable development of serpentine is noticed, and considerable work on a small hilly range towards lot 24, has disclosed good serpentine rock, with beautiful asbestos veins. Diabase, gabbro, and pyroxenite are frequent all along the serpentine belt; but proceeding farther north as far as lots 27 and 28, they become less and less frequent, and are replaced by granitic dikes of considerable dimensions. They constitute most of the dome-shaped hills which can be seen from the old Poudrier road, and occupy a great part of lots 27, 28, and 29. Turning now to the country west of the Poudrier road we can follow quite an extensive but low range of serpentine, the southeasterly wing of the great Black Lake productive belt. This low range has a course almost south, is interrupted occasionally by extensive dikes of granite, and to some extent, has been explored for asbestos with success. At the 'Southwark' mines on lots 27 and 28, range B, for instance, broad rock faces in some of the older pits show quite a con-

siderable development of excellent asbestos fibre. On lot 24 of the same range (B), and on others in the vicinity, good serpentine of the regular productive Black Lake type was noticed: some of it intersected by small veins of asbestos.

The extent of the serpentine to the east of Caribou lake cannot be determined at the present moment, due to almost insurmountable difficulties encountered in the attempt to penetrate the dense bushes which cover that part of the country. It is probable that the serpentine extends as far as lot 13, range XIII. There are two outcrops, one on lot 13, range B, belonging to the 'American Chrome Company,' and another on lot 13, range XIII; but as no outcrops appear in the northerly part of range XIII, it is difficult to say whether there is a direct connexion between these outcrops and the southerly part of the main serpentine belt. The northerly banks of Caribou lake are occupied by serpentine, and considerable work has been done here to open up chrome iron ore deposits, which appear to occur quite frequently along the shore. It appears that the contact line runs somewhere between a small island and the northern shore, because the rocks in the former are mostly composed of dioritic and granitic intrusions. The south shore of Caribou lake is composed mostly of diorite, and a big hill in a direction southwest 10° from the island, several hundred feet from the shore, is composed entirely of this rock. All the country north and west of Caribou lake, as far as Black lake, is occupied by serpentine, and the southwesterly contact line appears to run from the lower outlet of Caribou lake to the upper inlet of Black lake. The railway cut on lot 10, of range XIX, NW, is entirely composed of serpentine, as are all the numerous outcrops on lots 1, 2, 3, 4, 5, and 6. The contact then probably swings northeast, then northwest, as indicated on the map, and crosses in its turn to west of the lake. Its southwesterly course is probably along the northwesterly slope of the big Oak mountain, a hilly range three-quarters of a mile long, entirely composed of diorite.

Many outcrops of asbestos and chrome iron ore have been located all along the southern slope of the Big Ireland mountain: the most westerly of which appear to be those of the 'Premier Mining Company,' on Block B. From the 'Premier' mine northward the country is occupied by steep rocky mountain ranges, from 400 to 500 feet high; some of which are heavily covered with bushes and underbrush. Serpentine is the principal rock to be met with; it is flanked to the south and west by diorite: emerging sometimes in a quartz diorite; but following the Coleraine road northward we find a great development of greenish Cambrian schists, with a strike east-west.

The western limit of the great serpentine belt is made up of a number of elongated hills which reach a height of about 400 to 500 feet, and following in the main a line parallel to the highway at a distance of about three-quarters of a mile from the latter.

The most easterly occurrence of productive serpentine in the great vein-fibre belt is on lots 23 and 24, range II, Wolfestown, known as the 'Belmina' mines.

In the southern part of the township of Coleraine there is a considerable development of serpentine, as indicated on the map, especially between Little

St. Francis lake and another small lake 1½ miles to the east; but seeing that only chrome iron ore is being mined, and that no asbestos has ever been discovered here, a further description of this belt has been omitted.

Based upon the foregoing delimitation of the productive vein-fibre belt, there is a length of twelve miles from lot 23, range V, Thetford, to lot 23, range II, of Wolfestown; the greatest width being 3½ miles, as indicated by a line running along the concession road between ranges A and C, Coleraine. It is possible that the serpentine extends farther than the limits laid down in the map sheet, for reasons already explained; but from past exploration work it is safe to assume that, in the future, little additional productive ground will be added to that indicated.

Vein Fibre and Slip Fibre Belts Compared.

Based upon the foregoing discussion and description we arrive at the following summary of the outstanding economic features of both the 'vein-fibre' and 'slip fibre' belts:—

"Vein fibre" belt, or Typus Thetford.	"Slip fibre" belt, or Typus Broughton.
Asbestos occurs in seamy partings of the rock-mass, which represent the highest degree of serpentinization.	No seamy partings in serpentine.
Presence of asbestos in "veins."	Presence of asbestos as "slip fibre."
Presence of economic chromite deposits.	No chromite deposits.
Main constituents of rock-mass, generally termed serpentine: peridotite, olivine, serpentine-gabbro, true serpentine, pyroxenite.	Almost complete serpentinization; scattered presence of soapstone.
Presence of granitic dikes.	No granitic dikes.

PRESENT ECONOMIC FEATURES OF THE VEIN FIBRE BELT.

A glance over that part of the map sheet covering this serpentine belt will show that all the rich producing asbestos mines are located within 1½ miles from the northern fringe; and that along the southern border quite a number of chrome iron ore deposits will be noted; a fact which tends to the general induction that, wherever the ground is productive of chrome iron ore, asbestos is scarce.

It is true that in shaft No. 1 of the Black Lake Chrome and Asbestos Company, asbestos veins of a good quality have been discovered at a depth of about 400 feet, in association with chrome iron ore deposits. This shaft is located on the road leading from Black lake (from the old chrome mill) to Caribou lake

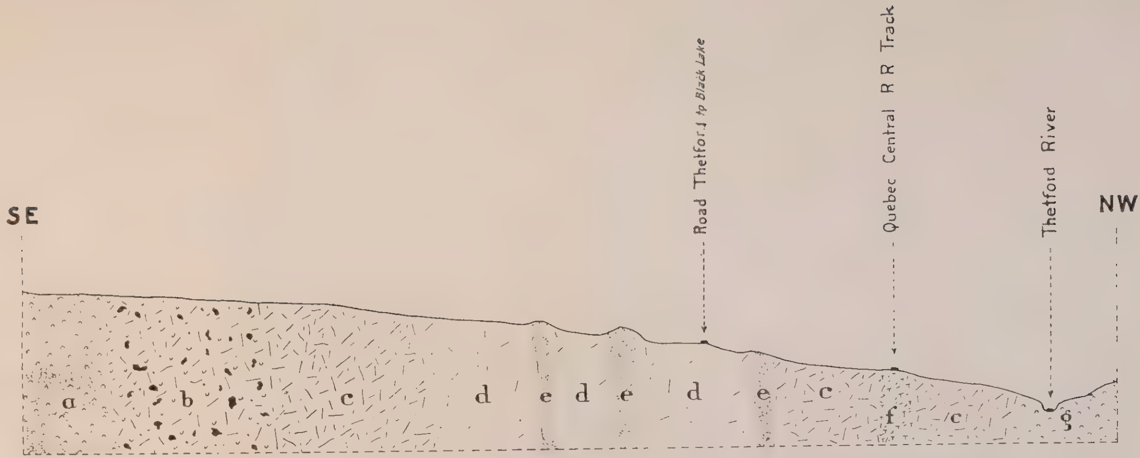


FIG. 7. Section through vein fibre belt in direction of Poudrier road, range A, Coleraine. (Scale, 2 inches to 1 mile.)

(a) Pyroxenite.
(b) Serpentine and chromite.
(c) Serpentine, peridotite.
(d) Serpentine asbestos (productive).
(e) Granite intrusions.
(f) Serpentine-gabbro.
(g) Gabbro and diabase.

about one-quarter of a mile from the track of the Quebec Central railway; but inasmuch as no actual mining for asbestos has been done in that shaft, so far, it remains to be demonstrated whether asbestos deposits of economic quantities occur together with productive chrome iron ore deposits. The discovery, however, is an important one for the district as a whole, showing as it does, that asbestos of good quality may confidently be expected at that depth, which will be dealt with further in the discussion on origins.

Diligent search and prospecting work, which has been carried on for many years all over this vein fibre belt, has brought to light the fact that, all the chrome iron ore deposits have been found within a certain zone, which, roughly speaking, starts from a point north of Oak mountain on Block A; traverses the upper arm of the lake; takes in all the chrome discoveries east of the railway, and ends in the deposits of the Canadian Chrome Company, on lots 16 and 17, range A. The approximate length of this zone is 6½ miles, and its greatest width in block A, east of the lake, Coleraine, 1¼ miles. In order to determine the probable productive acreage of asbestos in that part of the serpentine belt, the writer has estimated the acreage occupied by the chrome iron ore belt as follows:—

	Acres.
Total acreage of serpentine belt..	17,300
Approximate area of chrome iron ore..	3,500
	13,800

Deduct from this, 10 per cent for the granite dikes, dioritic intrusions, and serpentine gabbros, diabase, etc., which occur throughout the belt, and we have a total acreage of the vein fibre belt of 12,420. Of this amount only 1,100 acres are under development at the present time. Hence there are to-day, available for exploratory work, 11,320 acres. Parts of this area are known to contain excellent deposits of asbestos; and it is likely that additional ground may be located by diligent, systematic search. This area of 11,320 acres does not seem to be large; but it must be remembered that asbestos deposits wherever they are found in paying quantities, occupy whole blocks of the formation; consequently the available tonnage in any new mine may soon reach large proportions, although occupying a far smaller area on the surface in proportion to its yield than many another mine of low grade material.

In this serpentine belt two centres of asbestos occurrences are established, namely, Thetford and Black Lake, the distance between these two villages being five miles. It is a peculiar fact that—with the exception of the Southwark quarries—the whole stretch of ground between these two centres has not produced one single working mine. Whether this fact is to be attributed wholly to the unproductive character of the ground, or to the lack of systematic exploration work, the writer is unable to say. The ground is thickly covered with overburden and bushes, hence this may be one of the causes why more asbestos ground has not been opened up. Both the producing centres have been very successful; principally due to the excellent fibre the quarries produce. To the casual

observer asbestos fibre from Black Lake and Thetford might be the same. Manufacturers do not discriminate between one or the other—especially in the mill fibre. There are, however, a few slight differences, and while these may not influence the productive character of the districts mentioned, they are worth mentioning. The great silkiness of the Thetford fibre when freshly mined is lacking in the Black Lake variety; its colour when *in situ* is white, or yellowish-white, with a light-green tint; while the Black Lake fibre is dark green; seamy partings are more frequent, and the length of the fibre, generally, remains a little below the Thetford.

As a matter of fact the finest mineralogical specimens of chrysotile-asbestos come from Thetford. And having examined specimens of asbestos received from all points of the compass, the writer is forced to the conclusion that there is not one locality, either in the Eastern Townships or in the whole world, that can produce, at the present day, chrysotile-asbestos comparable to this so-called 'physical paradox' from Thetford: with its wonderfully slender, delicate, crystals and threads.

As to the serpentine occurring in the region under consideration, apparently several varieties can be recognized, which differ in importance as sources of supply: one is of the regular Thetford serpentine, with a greyish-green colour; of medium softness; tarnishing to some extent white with a blue hue when exposed to atmospheric action; it is compact, massive when *in situ,* affected by fissures and faults, some of them of considerable extent. This is the variety in which all the commercial asbestos is found; it forms a great mountain range about 600 feet high east of the town of Black Lake, where sixteen quarries are now in operation; it also forms the main body of productive serpentine upon which the town of Thetford is built, and where, for many years, the finest asbestos known has been produced.

The other, or non-productive variety, is a siliceous rock with a grass-green colour, much harder than the Thetford variety; when exposed to the air it tarnishes reddish-brown; it is brittle, much more fissured, and slickensides are plentiful throughout the rock; and they are generally characterized and identified by their association with wood-like aggregations of hard picrolite. This variety may be seen along the southern fringe of the big belt in range XIX, NW. West of Caribou lake—along the north shore—on the southerly slope of the big Black Lake serpentine range, there is another rock which is frequently taken for serpentine, and many prospect pits have been sunk in the same. This rock occurs along the mountainous range between Black Lake and Thetford, and is characterized by the wavy greenish shades which it produces when polished. It is not true serpentine, but fine-grained gabbro which to some extent has undergone serpentinization; it is much harder than ordinary serpentine, is less fissured and faulted, and never contains asbestos veins.

Granitic Dikes.

The serpentine is often cut by intrusive dikes of granite, which, as they fill fissures in the formation, appear to be of younger origin than the surrounding

rock. Mr. J. A. Dresser[1] takes a different view as regards their age. He admits the intrusion of these granitic dikes in some parts of Thetford and Danville, but maintains, at the same time, that much of the granite found throughout the region appears to be nearly, if not quite, contemporaneous with the parent rock of the serpentine. Mr. Dresser, however, advances this view only tentatively, owing to the lack of sufficient field study.

These granitic dikes are more frequent in the Black Lake region than in Thetford, and if their dimensions are large they interfere considerably with the systematic progress of the quarry work. They range in size from small bands of 1 and 2 feet, up to large intrusions of 50, 100, and 150 feet wide, and even more. Some of these form conspicuous hills between the villages of Thetford and Black Lake.

Very often these intrusive dikes can be seen in, or close to asbestos deposits: exerting, as they do, quite a favourable influence upon the presence of the mineral. Sometimes these dikes cut off good asbestos chutes entirely; but, as a general rule, good ground is found on the other side of the dike mass by driving through the same. The 'Bell' mines afford an excellent example of this economic procedure. Here, the northwesterly wall of the main pit—which is 190 feet deep—is formed by a large intrusive dike, and all alongside this good asbestos ground was encountered. For the purpose of exploring the formation towards the north, on the other (northwesterly) side of the wall, a tunnel was driven from the bottom of the pit ascending with a grade of 12 per cent, and the result—as far as the discovery of good asbestos ground was concerned—was quite a revelation to the owners; since not only did they find very rich ground all along the dike for a distance of 800 feet, with signs of still continuing, but this ground extended farther north for about 500 feet.

These granitic dikes cut the serpentine in almost every direction. Their dip is mostly vertical, but in several cases nearly horizontal beddings may be observed. The most extensive continuous dike so far observed in the district is the one which starts with and takes in the little rocky island in the centre of Black lake. Its general strike is northeast 65°, and large outcrops of this dike may be seen in the railway cutting below Black Lake station, near the Dominion mill of the Amalgamated Asbestos Corporation, terminating in a big outcrop at the foot of the big hill on the properties of the Black Lake Consolidated (below the Union pits). Its total length is 2½ miles, and its width varies from 50 to 250 feet.

The Danville-Eastman-Vermont Serpentine Belt.

Numerous outcrops of serpentine confined to a comparatively narrow but long strip of country occupied by the Cambrian formation, have been grouped together by the writer under the above name. These outcrops, although they appear to be all separated and detached from each other, form apparently part of the same belt; because of their relative location to each other and to the rather complex

[1] Transactions Can. Mining Inst., Vol. XII, page 173.

series of rocks belonging to different formations, as well as their arrangement in one location line taking the form of a flat curve, suggest their origin from one common source. It is quite probable, therefore, that outcrops which now appear entirely isolated, may yet be found to be connected with each other by intrusions of serpentine which are now concealed from view by the heavy humus covering the same.

The large serpentine outcrops, so far known, form part of a chain of hills and knolls distributed at intervals over a distance of sixty-two miles; the most northerly intrusions being those of the Tingwick mines, lots 20 and 21, range XI, of the township of Tingwick; while the most southerly ones are the outcrops near Mansonville, close to the Vermont boundary. From the first-named location—called the 'Doucet' and 'Martin' mines—the chain of serpentine hills takes a southwesterly course, covering the following lots:—

Lot 27, ranges X and XI, Tingwick.
Lots 7 and 8, range I, Shipton.

The Danville mines:—

Lots 9 and 10, range III, Shipton.
Lots 9, 10, and 11, range V, Shipton.
Lots 8 and 9, range IX, Shipton.
Lot 7, range XIII, Cleveland.
Lots 5 and 6, range XIV, Cleveland.
Lot 5, range XV, Cleveland.
Lots 19 and 20, range V, Melbourne.
Lots 21, 22, and 23, range IV, Melbourne: comprising the Rockland slate quarries.
Lots 17 and 18, range III, Melbourne.
Lots 16 and 17, range II, Melbourne.
Lots 15 and 16, range I, Melbourne.

From this last continuous serpentine range in Melbourne, the chain of outcrops takes a more southerly course, and comprises a number of small detached knolls in the township of Brompton; until we find a whole stretch of serpentine on both sides of Brompton lake. From here, the trend of the belt swings a little more to the west, and covers a number of serpentine hills and knolls on the southeast side of Long lake, in the township of Orford. The next outcrops are found around Orford lake and at the foot of Orford mountain, and straight west from here south of the town of Eastman in the township of Bolton. With few interruptions the serpentine continues from lots 1 and 2, in range VII; comprising the 'Benoit' and 'Parker' asbestos properties on the west side of Trousers lake, until on Orford lake we reach the Esty asbestos outcrops near Bolton Centre, about eight miles from Eastman, and comprising lots 19 and 20, range VIII. Continuing from thence strictly to the south, we find some small unimportant detached areas to the west of Lake Memphremagog; the last being the serpentine outcrops south of Mansonville, close to the Vermont (United States) boundary.

The Cambrian formation through which the serpentine intrusions, just described, appear, presents a great variety of characteristics: embracing slates, of all colours, sandstones, quartzites, quartziferous schists, and conglomerates. The quartzose rocks resemble those of the Sillery sandstones of the Quebec group; the slates are purple, black, green, and grey in colour; the conglomerates are, as a rule, classified into two kinds—those largely composed of pebbles of granitoid rocks, quartzites, and slates, while the other group is largely made up of diorite pebbles in a dark groundmass. Most of these rocks, especially in the northerly portion, are flanked by ridges of crystalline schists and gneissic rocks. In the southerly portion, the dioritic or related rocks form the easterly flank to the Cambrian rocks, and at many places serpentine merges gradually into these dioritic masses. This can be well seen to the west of Lake Memphremagog; these masses are associated primarily with the Cambrian, but also with the Pre-Cambrian, Cambro-Silurian, and even Silurian, strata. Where the alteration of diorite into serpentine took place the rock is generally fine-grained in the upper parts; while the lower parts are mostly coarse-grained. No chrysotile-asbestos of any value in either of these kinds of rocks has so far been found.

The productive value of this long serpentine belt, which is interrupted in numerous places by rocks of the Cambrian, has not been established yet to its fullest extent; since access to many of these serpentine ridges is extremely difficult, and since the area under question is largely covered with a heavy overburden and forest growth, rendering prospecting ineffective. It is evident, however, that if the thick forests were removed by fire—as in the Thetford-Black Lake area—much valuable asbestos ground would probably be located.

Chrysotile-asbestos has been discovered, and is partly mined in six places over this belt: namely, on lots 20 and 21, range XI, of the township of Tingwick (the Doucet and Martin mines); on lots 9 and 10, range III, in the township of Shipton (so-called 'Danville' mines); on lots 5 and 6, ranges XIV and XV, township of Cleveland; on the 'Parker' and 'Benoit' lots in range VII, township of Bolton; the Esty asbestos outcrops near Bolton Centre, and the asbestos outcrops near Mansonville. A description of all these occurrences will be found on pages 209-213.

ANALYSES OF SERPENTINE, ASBESTOS, AND ASSOCIATED MINERALS: ARRANGED IN TABULATED FORM.

Number.	Description.	SiO_2	MgO	FeO	Al_2O_3	Fe_2O_3	CaO	H_2O	Na_2O	MnO	Fe	K_2O	Loss on ignition.	Total.	Authority.
1	*Actinolite*, Elzevir, Ont	61·82	23·98	6·55	1·12		1·63	5·45							Prof. Coleman, Toronto.
2	*Hornblende—minerals—*														
	Tremolite, Richville, Gouverneur, N.Y.	57·5	24·9	0·2	1·3	0·2	12·8	1·3	0·7		0·8			100·3	Dr. Pirsson.
	Actinolite, Greiner, Tyrol	56·1	21·2	5·5	1·2	9·8	12·1	1·9	0·2		0·1			99·7	"
	Hornblende, Edenville, N.Y.	41·9	11·2	14·3	11·7	2·5	11·5	0·7	2·7		0·8			99·9	"
	Arfvedsonite, Greenland	43·8	0·8	33·4	4·4	3·8	4·6	0·1	8·1					100·5	"
	Claucophane, Island Syra, Greece	35·6	7·8	6·8	15·1	3·1	2·4		9·3					100·6	"
3	*Mountain cork*	57·20	22·85			4·37	13·39	2·43						100·24	Quenstedt.
4	*Crocidolite*														
	South Africa	49·6		19·80		22·00			8·60					100·00	
5	*Crocidolite*,	51·1	2·3	35·8				3·9	6·9					100·00	De Lapparent.
	(Locality unknown)	51·22	2·48	34·08			0·03	4·50	7·07	0·10				99·48	
6	*Picrolite*														
	East Broughton	37·88	43·29	0·36	1·10	2·70	0·82	14·32							Dr. M. Hersey, Montreal.
7	*Soapstone* (Canada)														
	East Broughton	61·50	33·03		0·89	0·11	0·16	4·25							Verger, Paris.
		62·80	33·10		0·20	0·25		3·60							"
		63·70	33·75	1·46	0·42			0·48					0·19		McCandless.
		56·20	32·65					2·64							Dr. M. Hersey.
8	*Soapstone*, Foreign—														
	Austrian	59·59	32·92	0·79	1·76		0·59	3·79				0·56			"Mineral Industry."
	French	50·91	24·86	2·58	13·19		1·82	6·64							"
	Italian	51·23	33·32	1·89	7·08		1·80	5·46				0·22			"
9	*French chalk*	62·80	33·50					3·70						100·00	"Asbestos" by Jones.
		63·49	31·75					4·76						100·00	
10	*Serpentine—*														
	Laurentian	39·34	43·02			1·80		15·09						99·25	Geological Survey of Canada, 1863, p. 472.
		41·20	43·52			0·80		15·40						100·92	
		44·10	40·05			1·15		14·70						100·09	
		29·80	38·40			7·92		13·80						99·92	
	Cambrian, Black Lake	39·60	40·71	0·99	1·45	3·74		12·98							Dr. M. Hersey.
		41·20	40·96	0·99	0·53	3·75		13·73							"
		38·90	42·93	4·44	2·01	3·53		8·47							"
		39·20	44·02	4·02	0·99	2·97		8·85							"

ANALYSES OF SERPENTINE, ASBESTOS, AND ASSOCIATED MINERALS: ARRANGED IN TABULATED FORM.—*Continued.*

Number.	Description.	SiO_2	MgO	FeO	Al_2O_3	Fe_2O_3	CaO	H_2O	Na_2O	MnO	Fe	K_2O	Loss on ignition.	Total.	Authority.
	Serpentine—Continued.														
	Decomposed serpentine, Lot 14, R. IX Broughton	34·70	32·10	4·20	2·95	6·50	......	3·96	......	.....	.....	21·03	......	......	Dr. Milton Hersey.
	Lime serpentine	27·20	8·51	15·28	26·75	3·57	11·90	7·60	.....	.....	.....	.....	.....	.....	"
	"	41·15	12·77	10·82	13·21	2·52	16·78	3·40	.....	.....	.....	.....	.....	.....	"
	East Broughton (disassociated from asbestos)	41·10	42·39	0·99	1·02	2·58	.....	12·10	.....	.....	.....	.....	.....	.....	"
	Richmond	38·00	38·92	1·32	2·89	7·49	....	10·90	....	.....	.....	.....	.....	.....	"
	Mansonville	37·80	38·52	0·80	1·83	7·27	......	13·46	.....	.....	.....	.....	.....	.....	"
	Eastman	40·42	40·62	0·47	1·92	2·45	......	13·45	.....	.....	.....	.....	.....	.....	"
	Thetford	40·76	42·32	0·49	....	3·05	0·35	13·60	....	.....	.....	.....	.....	.....	"
11	*Chrysotile-Asbestos*—														
	Thetford	39·05	40·07	0·87	3·67	......	......	14·48	.....	....	.....	.....	.....	.....	Dr. Donald, Montreal.
	Black Lake, B. C. quarries	39·36	42·15	3·51	....	....	......	14·50	.....	.....	.....	.....	.....	.....	Dr. Milton Hersey.
	Black Lake, Standard quarries	40·42	41·85	2·60	0·82	....	......	14·37	....	....	.....	.....	.....	.....	"
	Black Lake, Southwark mine.	39·22	40·27	2·26	3·64	......	....	14·37	.....	....	.....	.....	.....	.....	Dr. Donald.
	Locality not known.	39·60	41·99	1·62	....	2·58	....	14·44	.....	.....	.....	.....	.....	.....	Dr. Milton Hersey.
	East Broughton, exact locality not given	40·87	41·50	2·81	0·90	....	......	13·55	.....	.....	.....	.....	.....	99·63	Dr. Donald.
	East Broughton, Glasgow and Montreal mine	41·90	42·50	0·69	0·89	......	....	14·05	.....	.....	.....	.....	.....	.....	"
	East Broughton, Frontenac.	39·20	42·97	2·95	....	....	....	13·87	.....	.....	.....	.....	.....	.....	Dr. Milton Hersey.
	East Broughton	41·20	40·83	0·45	0·12	3·77	......	13·29	.....	.....	.....	.....	.....	.....	"
	Thetford, Lot 2, R. V	40·76	42·32	0·49	....	3·05	0·35	13·60	.....	.....	.....	.....	.....	.....	"
	Broughton, Lot 14, R. XI	46·60	11·87	12·35	3·44	2·70	15·80	2·92	.....	.....	.....	.....	.....	.....	"
	Eastman	40·42	40·62	2·92	1·92	......	......	13·45	.....	.....	.....	.....	.....	.....	"
	Danville	41·84	41·99	2·23	....	......	.....	14·28	.....	.....	.....	.....	.....	.....	Dr. Donald.
		42·64	39·54	3·66	....	......	.....	14·31	.....	.....	.....	.....	.....	.....	"
	Laurentian, Templeton	40·52	42·05	1·97	2·10	......	......	13·47	.....	.....	.....	.....	.....	100·10	"
	Italy	40·30	43·37	0·87	2·27	......	...	13·72	..	.....	.....	.....	.....	100·53	"
	Western Australia	42·20	40·75	2·08	1·60	....	.....	14·01	.....	.....	.....	.....	....	....	Dr. Milton Hersey.

Asbestos Fibre compared with other Organic and Inorganic Fibres.

In comparing asbestos with any other fine organic or inorganic fibre, structural differences cannot be at once perceived with the naked eye; but when these fibres are placed under the lens or microscope, certain peculiarities in their structure may be at once recognized.

For instance, fine silk threads and crude Thetford asbestos fibre, laid side by side, appear at first sight to be identical; whereas the former is of organic, while the latter is of inorganic origin. Manufacturers of asbestos goods, how-

FIG. 8.—Fibre of raw silk.

ever, realized at once the totally different character of these fibres when they commenced to spin the asbestos; they found that special treatment had to be applied, and special machinery designed in order to make the very fine threads, of which the fibre is composed, adhere together; thus facilitating the manufacture of fine asbestos yarn to be used in spinning. Wool fibre, cotton fibre, silk threads, spun glass, quartz fibre, etc., all possess the same outward characteristics as asbestos fibre: they may be drawn out in fine threads, to be used in spinning. The question naturally arises, therefore, as to what constitutes the structural difference between all these delicately fibred materials. We perceive at once the difference in wool, cotton, and silk, when they are made up in garments, but the case is entirely different when single, minute threads are laid side by side. As stated above, with the naked eye differentiation is almost impossible, and microscopical examination has to be resorted to. The sheep's wool fibre illustrated in Fig. 9, magnified 600 diameters, has a peculiar serrated and notched appearance, similar to some plants of the corniferous type. The outer structure is formed by irregular shaped, scaly bands, or plates, which overlap each other. These peculiar projections act like teeth, and cause the wool

fibre to cling together when twisted. The manufacturers have recognized the value of these scaly bands and the more numerous they are the higher are the prices paid for such qualities. In fine Saxon wool it is said that on one lineal

FIG. 9.—Fibre of sheep's wool. Magnified 600 diameters,

inch of thread there are no less than 2,720 of these scaly bands—technically called imbrications; whereas in Leicester wool they are said to number only 1,850. Cotton fibre, especially the raw filaments, as seen under the lens, has a

FIG. 10.—Filaments of raw cotton.

much twisted appearance, and its structural difference from asbestos fibre consists in the irregular and rough surfaces, which render it readily adaptable for spinning. The usual method of determining the quality of cotton fibre, by feeling it with the fingers, is necessarily a very crude one; because—according to

T. Gray[1]—the thickness of ordinary cotton fibre varies from $\frac{1}{900}$ to $\frac{1}{2000}$ of an inch. 'Mississippi' delta fibre, which is considered, at present, the finest cotton

FIG. 11.—Spun glass.

in the world, presents under the microscope a beautiful structure, and perfect development. The actual length of this fibre is $\frac{1}{100}$ of an inch.

FIG. 12.—Quartz fibre.

According to the authority above quoted, from 300 to 800 twists of cylindrical tubes are in one lineal inch of cotton fibre.

[1] A lecture delivered before the 'Franklin Institute.'

Mr. James Thompson[1] describes cotton fibre as follows:—

'The filaments of cotton are transparent glassy tubes, flattened and twisted round their own axis. A section of the filament resembles a figure of 8, the tube, originally cylindrical, having collapsed most in the middle, forming semi-tubes on each side, which give to the fibre when viewed in certain lights the appearance of a flat ribbon with a hem or border on each side. The twisted and corkscrew form of the filament of cotton distinguishes it from all other vegetable fibres.'

Silk fibre possesses a multitude of peculiarities which, under the lens and microscope, distinguish it readily from any other fibre, organic or inorganic. In the first place, each silk thread is composed of two separate filaments, which are cemented together longitudinally by the secretion from a small gland situated near the pores, and the quality of the silk depends primarily on the character of these secretions. Silk fibre on the surface resembles a fine glass rod; the line of junction of the two filaments is made perceptible by a fine groove, which is filled by the secretion—a gelatinous substance.

Silk fibre is not, as generally supposed, of great smoothness; but yet possesses no rough surfaces, since it is twisted spirally. It can be readily spun, but cannot be felted unless mixed with some foreign material.

C. V. Boys[2] states that, two silk filaments, when separated and washed, exhibited remarkable tensile strength: they were able to sustain a weight of 60 grains before breaking. This authority says that the carrying power is equal to from 10 to 20 tons per square inch.

It is said that artificial silk has many advantages over natural silk, and much importance is given to a process invented some twelve years ago by Count Hilaire de Chardonnet, Paris, and Dr. Lehner, at Bratford. However, so far the introduction of this new article has made no great strides, and every year witnesses an increase in the importation of raw silk into the United States, and Canada, from China—the home of the silk worm.

Having described the principal organic fibres which very closely resemble asbestos fibre in outward appearance, it is now purposed to describe the physical appearance of asbestos fibre itself, and to indicate where it differs from similar substances.

A number of microphotographs have been made of asbestos fibre from different Canadian asbestos fields, as well as from foreign countries. In all these illustrations it will be perceived that, asbestos fibre is almost identical in structure with the organic fibres already described: namely, that each apparently single fibre is actually composed of a series of fine filaments. Under a very powerful microscope they are seen to be composed of even finer fibres, and for micrometrical purposes, fibres of 1/3000 of an inch in diameter have been successfully employed in the laboratory. Asbestos fibre has no rough, imbricated surface like wool fibre; but resembles a fine polished metal rod, free from any serrated parts, and is altogether wanting in the clinging projections common to the organic fibres already described: which explains the difficulty of the early manufacturers in their first attempts to spin it. The tensile strength, however, of fibre asbestos is quite equal to that of silk fibre. The writer, in the

[1] James Thompson on 'Mummy Clothes,' 1891.
[2] Paper read before the Royal Institution in June, 1889.

prosecution of his studies on this subject, suggested to Dr. Haanel, Director of the Mines Branch, Department of Mines—the advisability of the Dominion Government building a special machine for the purpose of determining the breaking strength of the fibres; this was done, but unfortunately the tests failed entirely, owing to the fact that each thread, as already explained, is composed of a series of exceedingly fine, minute filaments, which, when torn, slip past each other instead of breaking. In the asbestos industry generally, tensile strength tests are made in the factories with asbestos yarn or rope: and although absolute accuracy cannot be claimed for these tests, yet they are sufficiently accurate for all practical purposes.

Many difficulties were encountered in the attempt to study the character of the fibre under the microscope. When asbestos fibre is finely drawn out and separated into threads, or spider-like filaments, their highly refractive qualities are at once apparent, and render the detection of irregularities in the structure of the filaments, or their special characteristics for the purpose of differentiation, extremely difficult. Optically, all asbestos fibres show extinctions parallel with the axis of elongation: they are devoid of any pleochroic qualities. The outlines of the fibres, when examined under high, microscopic powers, are round, prismatic, and polygonal; but the majority are polygonal or round. All fibres exhibit—when examined under a common lens—the same characteristics of 'crowding': that is, grouping together of numerous fine threads within what appears to be a single fibre. The actual size of the fibres of all varieties—i.e. the diameter—is consequently indefinite, and although careful measurements have been made, which show that the smallest diameter so far determined is 0·00075 millimetre, it can be demonstrated that even the finest filament measured is composed of fine threads, evidencing that its division is infinitesimal.

The writer has had the diameters of the smallest obtainable fibre of many asbestos varieties determined by Dr. H. T. Barnes, Professor of Physics, McGill University, who kindly consented to undertake this work, and furnished the following data:—

Locality.	Smallest Diameter Millimetres [1].	Number of Fibres. Per Lineal Inch.
Canada—		
Thetford	0·001	25,000
Black Lake	0 001	25,000
Broughton	0·0015	16,650
Templeton	0·0015	16,650
St. Adrien	0·002	12,500
Carded asbestos	0·001	25,000
United States—		
Grand cañon, Arizona	0·00075	33,325
Casper mountain, Wyoming	0·00075	33,325
Russia—		
Ural mountains	0·00075	33,325
Siberia—		
Yenisei river	0·001	25,000
Africa—		
West Griqualand	0·009	27,775
Transvaal (Carolina district)	0·0015	16,650
Western Australia—		
Pilbarra district	0 0015	16,650

[1] 25 Millimetres = 1 inch.

Much difficulty was experienced in obtaining some of the microphotographs of fibres; since their highly refractive qualities made a 'clean-cut' impregnation on the films an impossibility; and it was necessary to use polarized light only, the single exposures being six hours. A glance at the 16 microphotographs will show that, the fibres taken from the localities indicated, differ somewhat from each other physically. The following is a general description of the characteristics of each exposure.

In Plate XVIII several filaments of 'spun glass' are shown. Under high microscopic power the rod-like metallic nature is at once apparent: some of the threads are hollow, in contradistinction to asbestos fibre.

Plate XIX shows Thetford fibre. The two strings, respectively, marked *a* and *b* in the 'micro,' although composed of thousands of individual fibres, have each, all the characteristics of perfect crystals: the entire bundle exhibiting the optical qualities of a single fibre.

The Thetford fibres are beautiful in appearance; and when drawn out with the finger have an unctuous feel: in fact possess all the qualities of genuine silk fibre. When *in situ,* they can be distinguished in most cases from any other asbestos fibre; but when drawn out, or subjected to mechanical treatment they lose their distinctiveness. In the 'micro' one bundle (*a*) is shown broken, and the fine ends can be readily seen. The two fibre bundles have been subjected to torsional movements and display immediately over the twisted points their numerous composite fine filaments, which appear in the 'micro' as dark lines across the fibres.

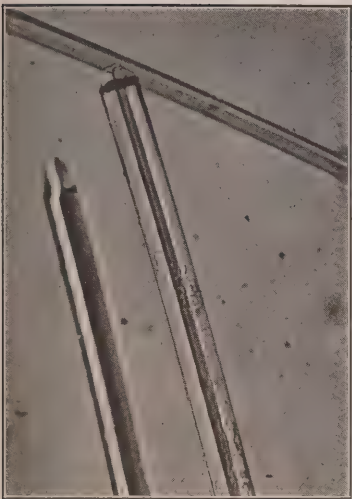
In Plates XX and XXI Black Lake fibre is photographed, showing on one, a fracture across the fibre, and in the other the broken ends of a bundle of fibres. Of special interest in Plate XXI is the infinitesimally fine fibres of which the bundle is composed.

Plate XXII illustrates a fine bundle of fibres from the Laurentian deposits, twenty miles north of Ottawa. In contradistinction to the Thetford and Black Lake fibre, its rod-like, smooth surface, resembles that of a polished metal; and on account of its exceptional refractive qualities the fibre, when exposed to polarized light, is very difficult to photograph. The nature of what is supposed to be single fibre threads is seen in Plate XXIII. This 'micro' is highly interesting; for it shows distinctly that the fibres are not, as is generally supposed, all like polished steel rods, but fine imbrications and apparently rough undulating surfaces are plentiful. These fibres resemble more a rough wooden stick with notches and many other irregularities; but it is quite clear that even if these in any way detract from their smoothness, they add, in reality, very little to their spinning qualifications, which presupposes the existence of a considerable number of teeth-like imbrications on the surface.

Plate XXIV represents a break in a single fibre, the fracture being represented by the white portion in the centre of the photo. It illustrates again in a general way the extremely fine division of the fibre—specially noticeable above the fractures.

Plates XXV and XXVI, fibres from Russia, and Italy, are illustrated. No imbrications or any other surface irregularities in the fibre can be seen; and

PLATE XVIII.



Spun glass. Magnified 200 diameters.

PLATE XIX.

Thetford fibre. Magnified 250 diameters.

PLATE XX.

Black Lake fibre. Magnified 350 diameters.

PLATE XXI.

Black Lake fibre fracture. Magnified 350 diameters.

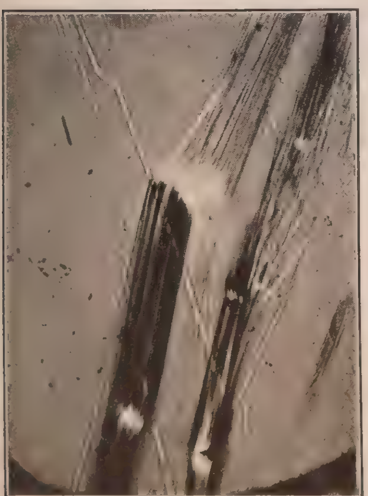
Plate XXII.

Templeton asbestos fibre. Magnified 350 diameters.

Plate XXIII.

Thetford fibre ends. Magnified 200 diameters.

Plate XXIV.



Break in Thetford fibre. Magnified 200 diameters.

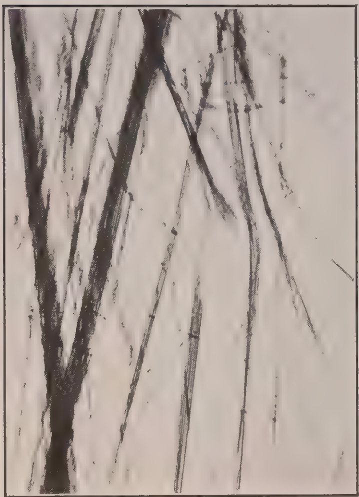
Plate XXV.

Fibre from the Urals, Russia. Magnified 200 diameters.

PLATE XXVI.

Fibre from Aosta valley, Italy. Magnified 100 diameters.

PLATE XXVII.



Asbestos fibre from West Griqualand, South Africa. Magnified 250 diameters.

PLATE XXVIII.

Break in asbestos fibre from West Griqualand, South Africa. Magnified 350 diameters.

PLATE XXIX.

Fibre from the Carolina district, Transvaal. Magnified 200 diameters.

PLATE XXX.

Fibre from the Pilbarra district, Western Australia. Magnified 200 diameters.

PLATE XXXI.

Break in fibre from the Pilbarra district, Western Australia. Magnified 150 diameters.

PLATE XXXII.

Fibre from Casper mountain, Wyoming, U.S.A. Magnified 150 diameters.

PLATE XXXIII.

Break in fibre from Casper mountain, Wyoming, U.S.A. Magnified 150 diameters.

under the microscope, no essential difference can be perceived between these and the Canadian fibre.

Plates XXVII and XXVIII represent the blue variety of chrysotile from West Griqualand, South Africa. It exhibits a very coarse and fluffy appearance compared with the Canadian and Russian mineral, and a fracture in the fibre—as represented in Plate XXVIII—shows distinctly the extremely minute filaments of which a single fibre is composed.

The other microphotographs represent fibres from the Transvaal; Carolina district, Pilbarra, Western Australia; and Casper mountain, Wyoming, U.S.A. These fibres show the harsh, metallic, rod-like structure, which, to some extent, differentiates them from the Canadian varieties.

The results of the microscopical investigations so far conducted with fibres from different parts of the world, may be summarized in the following points:—

(1) The structure of asbestos fibre outwardly is almost identical with organic fibres, namely, that each apparently single fibre is composed of numerous, exceedingly fine filaments.

(2) The difficulty of spinning asbestos fibre lies in the fact that, unlike silk, cotton, or wool, no imbrications or teeth-like obstructions are in evidence on the surfaces on any asbestos fibre whatsoever.

(3) The variations in outward structure of the fibres examined are not strong enough to form a basis of reliable differentiation. One fact, however, seems to stand out, and that is, the glassy, or metallic, rod-like appearance of many asbestos fibres under high microscopic powers—with the exception of those from Thetford-Black Lake, Canada, and Russia.

Origin of Chrysotile-Asbestos.

The writer has set forth in the first edition of his Monograph on Asbestos, a synopsis of what was at that time (1904), generally known regarding the origin of chrysotile-asbestos, together with his own ideas and conclusion on the subject. During the last six years, however, several new and important facts have been brought to light, which, although not explaining all the observed phenomena in connexion with the mineral, tend to clear up some important points; especially as regards alteration of pyroxene-olivine to serpentine, and its bearing upon the formation of fissures. Before entering into a dissertation on this subject, however, it may be an advantage to quote the theories already advanced by noted scientists.

Mr. Hyde Pratt [1] summarizes his ideas as follows:—

'There is but little information to be had regarding the origin of chrysotile, the fibrous variety of serpentine. Its occurrence as a fibrous silky product lying in narrow seams in the main mass of serpentine and having almost identically the same chemical composition as the enclosing rock, which is known to be an alteration product and not the primary rock, raises some puzzling questions regarding its formation. There are a number of points to be taken into consideration—the relation of the chrysotile to the serpentine in which it occurs; the relation of the main body of serpentine

[1] The United States Geological Survey, 1904, Bulletin on Asbestos.

to the enclosing country rocks; the mineralogical and chemical relation of the chrysotile to the mass of serpentine; and the origin of the rocks from which the main mass of serpentine has been derived.'

'It can be conclusively shown in nearly all cases that the serpentine in which the chrysotile-asbestos is found is of igneous origin. Some of the main points leading up to this conclusion are: the presence in the serpentine of the mineral chromite, either as small grains or as segregated masses; the almost entire absence of any carbonates, except those which are of undoubted secondary origin; the occurrence of small masses of gneiss, granite, or other rocks entirely surrounded by the serpentine, which have undoubtedly been broken off from the main masses of these rocks during the intrusion of the rock of which the serpentine is an altered facies; the blunt, lenticular form which so many of these masses of serpentine are observed to have; and the sharp line of separation of the masses of serpentine from the surrounding country rock.'

'The original rock in cooling would solidify first along its contact with the rocks through which it had penetrated and where it was in contact with any included masses of the country rock that had been broken off during the intrusion of the molten magma. The outer portions of the molten rock would thus cool much more suddenly than the interior portions, and there would be a tendency for them to develop cracks and parting planes. In the alteration of these primary rocks to serpentine, through the agency of aqueous solution, vapours, etc., there would be perhaps, to some extent at least, a widening of these cracks, but in the end they would be filled with serpentine deposited from aqueous solutions from their walls, and the resulting fibrous structure of the serpentine filling these seams represents the nearest approach to a true crystallization that the mineral serpentine assumes, except when it is found as pseudomorph after another mineral. It is probable that this chrysotile-asbestos may have been formed some time before the complete alteration of the primary rock into serpentine. This is emphasized by the fact that in the southern part of the United States where these basic magnesian rocks have been but partly altered to serpentine, seams of chrysotile-asbestos are occasionally found, and that in other cases seams of serpentine are found almost entirely enclosed by a peridotite rock which is altered but little into serpentine. Then again, it may be that in the first alteration of the basic magnesian rocks, the seams and crevices are filled with serpentine which has been derived from the main mass of the basic magnesian rock, and that later, during the process of complete alteration of the rock into serpentine, these seams have become asbestiform, due to the action of aqueous solutions.'

'As one studies these basic magnesian rocks in their primary, or nearly primary condition, as found in the various peridotites of North Carolina, South Carolina, and Georgia, it becomes almost immediately evident that these rocks are badly cracked and seamed in proximity to their contact with the country rock through which they have intruded, this being especially true of those containing but little chromite or corundum. During the process of alteration, these seams and crevices have become filled in some instances with a clay-like material; in others, with a compact serpentine; and in still others, with the fibrous variety of serpentine. These seams and crevices have no regularity, they are apt to run in nearly all directions and are not of any considerable length.'

'With very few exceptions, all the fibres of the asbestos are standing at nearly right angles to the sides of the seam, which would conclusively show that they were not formed by any shearing movement of the rocks. In a

few exceptional instances, chrysotile-asbestos has been reported where the fibres were lying lengthwise with the seams, and in these cases there may have been shearing movements of the rocks, which have resulted in the formation of a fibrous serpentine.'

'Another point of interest to be noted is that in those bodies of serpentine containing a large quantity of chromite, corundum, genthite, or garnerite, there is little or no chrysotile serpentine. This would seem to indicate that the chromite and corundum had in their separation from the molten magma interfered with the extensive formation of the cracks which are necessary to the formation of the chrysotile serpentine.'

Dr. R. W. Ells of the Geological Survey, Canada, gives his opinion as follows:—

'The asbestos veins which traverse the serpentine in all directions in the asbestos-bearing portion, probably owe their origin to fissures which have been formed in the rock-mass as a result of some one of the several periods of movement. That some of them were formed prior to the final crushing is probable, since occasional veins are found in the crushed condition; the greater part of these veins, however, is but little disturbed, and the fibres are still at right angles to the sides of the fissure.'

'The intrusion of the white granite dikes has probably exercised some influence in this direction, since often in the mining, as the dikes are approached the veins increase in number, as if the rock had been opened up by their action. Sometimes masses of granite invade the serpentine and cut off the asbestos-bearing rock entirely, so that the workings have to be abandoned. When a face of good asbestos rock has been cut off by the action of faults, good ground is generally found again by driving for a short distance through the barren wall.'

'In whatever way the fissures were caused, and it is very probable that they have been formed by the great processes of metamorphism to which the rocks were exposed in the change from dioritic matter to serpentine, the vein asbestos appears more naturally to have been produced by a process of segregation of serpentinous matter from the sides of the fissure very much as ordinary quartz in many mineral veins is known to have been produced, the segregated or infiltrated matter gradually filling the original fissure and meeting at or near the centre, in proof of which the presence of a comb or particles of iron is very often found occupying the centre of the vein, and quite frequently these iron grains assume sufficient size to form a regular parting of iron ore in the fibre. In this respect asbestos veins resemble very closely mineral veins with quartz or calcite which frequently contain alternate layers of ore on either side of a central comb of crystals. The arrangement also of the fibre at right angles to the sides of the containing fissure, except where the rock has been disturbed, is confirmatory evidence in the same direction.'

Mr. George Merrill holds that the crevices in the serpentine are due to shrinkage, such as is incidental to the change of a highly hydrated colloidal substance into a less hydrated and more solid form, and perhaps also to a loss of silica, as suggested by Professor Kemp. He compares them to the shrinkage cracks which appear in clay on drying, or those which result from the shrinkage of a gelatinous mass of iron carbonate, as in the so-called septarian nodules of clay-ironstone. The masses of serpentine are supposed to have undergone a process of hydration and swelling, with a subsequent shrinkage which produced cracks.

As to the filling of these cracks, Merrill refers to a fibrous structure formed under quite similar conditions in gypsum, and also, but more rarely, in calcite. In the first-named the crystallization apparently takes place by a process of growth from one of the walls; considerable force having been manifested; sufficient to rupture the rock-mass in which it is taking place. Whether or not such conditions existed in the case of asbestos veins still awaits proof.

> Mr. Merrill, continuing his argument says: 'It is noted, however, that veins of any considerable width rarely show continuous fibres extending from side to side. In most cases the continuity is interrupted by small fragments of the wall rock; or again, where this is lacking, there exists at some intermediate point between the walls, a break or line of separation, as though the crystal fibres had been pushed outward from either wall until their extremities met. In many such cases the growth has continued until the fibres are pushed past one another to a slight extent, the line of contact thus becoming jagged or saw-like. Again, there are other indications of pressure from the direction of the walls, manifesting itself most frequently in a crimpling of the fibres.'

In a later publication, Mr. Merrill[1] refers again to this subject as follows:—

> 'There is, however, apparently no doubt that they are altered highly magnesian igneous rock. Now, the process of hydration (serpentinization) in rock of this class must, provided there is no loss of material by solution, result in expansion. T. S. Hunt showed that the passage of olivine into serpentine under such conditions would result in an increase in bulk amounting to 33 per cent. That some material is almost invariably lost we have abundant proof. Nevertheless, expansion at some stage in the serpentinizing process usually results, and it is to the incidental readjustment of the rock-mass that is commonly attributed the characteristic jointed condition and the slickensided surfaces.'

Mr. Merrill mentions further, that in the course of a discussion between Professor T. N. Dale and T. F. Kemp, the suggestion was made that the fissures might be the result of tension, or a stretching movement; or that they are either due to dynamic causes, or produced by shrinkage, due to a loss of silica in the process of alteration.

Dr. A. P. Low, ('The Chibougamau Mining Region,' Geological Survey Report, 1906), expresses himself on the subject as follows:—

> 'The cracks were probably formed by shrinkage of the mass and perhaps in part by the crushing action of the same pressure which lengthened and flattened the serpentine areas, and at the same time made the associated rocks schistose. The asbestos appears to the writer to have been deposited in the cracks under great pressure from superheated waters, which, penetrating the rock, absorbed the material of the serpentine until the solution became a saturated one. With cooling, the mineral would be deposited in the cracks. In the Thetford and Black Lake areas, masses and dikes of granite have been intruded into the serpentine, and these probably account for the necessary pressure and heated waters to form the asbestos there.'

Mr. John A. Dresser[2], does not believe in the theory of the formation of fissures and subsequent deposition of asbestos fibre therein; he argues:—

> 'While the veins run in all directions through the rock, the larger veins are usually those along joint planes. Of these, the horizontal series, which

[1] Bulletin of the Geological Society of America, Vol. 16, pages 131-136.
[2] Canadian Mining Institute, Vol. XII, 1909, pages 170-171.

are sometimes over two inches wide and extend for 100 to 200 feet, could never have been open fissures, nor is it conceivable that small areas of rich ground occasionally found where there may be 12 or 14 per cent of asbestos could ever have had as many open fissures as they now have filled veins. It, therefore, seems most probable that a process of replacement of the wall rock has gone on contemporaneously with the deposition of asbestos. The film of iron ore, or the parting so common in the veins, would thus be the beginning of the vein, and the chrysotile crystals by growing outward on either side would thus have formed the wider veins as the serpentinization of the wall rock advanced. The asbestos can only have been formed after the serpentinization of adjacent parts of the rock.'

The theories advanced by the foregoing authorities clear up many points in connexion with the formation of fissures in the serpentine, and deposition of asbestos fibre therein; but there are still many questions to be answered.

Assuming that the serpentine in the Eastern Townships is an alteration product of highly magnesian igneous rock, an important point remains to be explained, and that is, the relation between the increase in volume through hydration, and the formation of these fissures as receptacles for the fibre.

Bearing on the above, Sterry Hunt[1] has shown that, the alteration of olivine into serpentine would result in an increase of volume amounting to over 30 per cent. Now, admitting that some of the silica—or even if all that material—is lost in the process of hydration, there must still have been a great expansion at some stage of the process, and this expansion must at the same time mean increased pressure in the interior of the rock, since the surrounding formation undoubtedly hemmed in these rocks, and did not allow of an easy expanse through increase in volume. It was thus impossible that fissures could have been formed at this stage.

It seems probable, however, that as soon as the process of alteration was finished, a readjustment in the rock-masses took place; but in the opinion of the writer, this readjustment resulted in the formation of joints and slickensides, just as we find them, at the present time, in the quarries. This theory is substantiated by the fact that, in the mines at Thetford, numerous places can be seen where these fissures (now asbestos veins), cut right through joints and slickensides. The next question arising is, how have these fissures been formed? Was it through shrinkage due to a loss in silica, or due to shrinkage of the rock mass through cooling? Now, if the cracks were formed through the loss of silica, they would have been formed during the process of alteration, that is, before the joints and slickensides were formed; but this would have been impossible—as already explained.

The most rational explanation, and the one which seems to gain most support is, that the formation of cracks was caused by cooling and shrinkage of the rock-masses, similar to the formation of cracks caused by the shrinkage of a gelatinous mass of iron carbonate, in the so-called septarian nodules of clay ironstone as suggested by Merrill. It is also probable, however, that the intrusion of those granitic dikes so frequently met with in the serpentine masses has caused,

[1] Mineral Physiology and Physiography, page 506.

or facilitated to a great extent, the formation of numerous fissures in the immediate proximity of these intrusions: by rapid dehydration due to the agency of heat. The fact outlined in a preceding paragraph, namely, that very frequently an accumulation of asbestos veins can be noticed in approaching these intrusive dikes, seems to substantiate this theory.

The latter presupposes the presence of water in greater quantities than is admissible in the formation of serpentine; but this condition is quite probable, since the rock-masses must have all been in a semi-magmatic state, in order to undergo these varied changes. The assumption, however, that the fissures in their entirety are the result of a cooling off in the rock-mass, where the latter was in contact with the country rock which it had penetrated, cannot be very well upheld, in view of the fact that in many portions of the serpentine—even when in contact with the country rock, no asbestos veins are found; while in the same serpentine mass—sometimes far from the contact—a large number of veins may occur.

With regard to the manner in which these cavities or fissures were filled, it must be stated that this is a subject upon which only one or two opinions have, hitherto, been advanced: due to the fact that the formation of such wonderfully delicate and silky fibre has no parallel in nature.

G. P. Merrill[1] speaks of a similar crystallization as taking place in gypsum and calcite under almost identical conditions. In the first-named, the crystallization apparently takes place by a process of growth from one of the walls, considerable force being manifested, sufficient it may be to rupture the rock-mass in which it takes place. It is questionable, however, whether such conditions existed in the case of asbestos; hence we have to turn to other observations for an adequate explanation. We know that asbestos fibre is an example of fibrous crystallization due to crystallizing across a fissure; but why it is so finely fibrous, or how it gained its present form, cannot be explained to satisfaction. Dana refers to this point only in a general way in his Systematic Mineralogy, 1850: Section II, Theoretical Crystallogeny, page 124, as follows:—

> 'In aggregated crystallizations there is a mass of material entering into the solid state together, and no opportunity exists for single crystals to perfect themselves. While a liquid mass is cooling, whenever the temperature of solidification is reached, at numberless points throughout the mass, crystallization will begin, and together an aggregation of crowded crystals or grains is produced, with no external regularity of form; in other words the granular structure. The same will happen in a crystallizing solution if the process goes on rapidly.
>
> 'When a solution is spread thinly over a large surface, minute crystalline points encrust the whole, and if the solution be gradually supplied, as crystallization goes on, it is obvious that the minute points may elongate into crowded prisms of fibres, producing a fibrous structure. Such a structure is common in narrow seams in rocks, and the fibres are usually elongated across the seam.'

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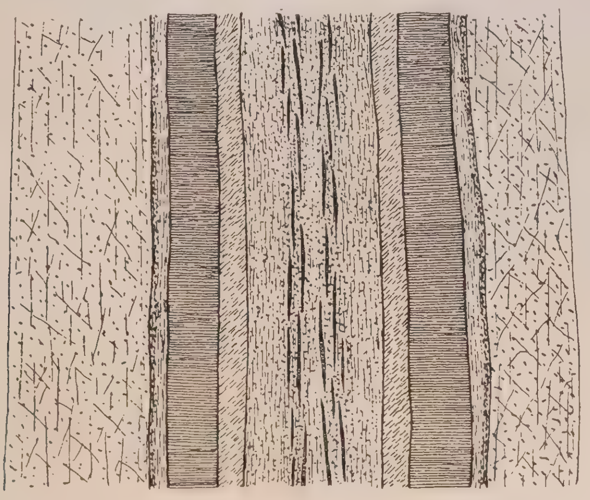
[1] The formation of gypsum in caves. Proc. United States National Museum, Vol. XXII, 1894, page 81.

It seems that this paragraph refers to chrysotile; because the crystals of the same are elongated across the seam in the precise mode described. Possibly the fibres of chrysotile, like those of other fibrous minerals, have been produced by a like process of crystallization to that which formed the long circular crystals occasionally found in quartz. Chrysotile may have been an extreme example of crystallization which took place under conditions of high temperature and extreme pressure. Mr. Gosselet[1], referring to crystalline minerals generally, holds that they owe their origin to the action of superheated water in the rock: a view in which Dana concurs; for he admits that the cause of metamorphic changes is subterranean heat, together with moisture and pressure. It is a well-known fact that rapidity of cooling tends to produce the glassy condition of minerals; while slow cooling is the condition most favourable to crystallization, and for this reason: if we presuppose an intense heat, extreme pressure, and a slow process of cooling, a fine delicate crystallization will be the ultimate result. It is very probable, therefore, that in the case under consideration, the serpentine has passed through all the above-mentioned stages, and produced what is now called the 'mineralogical paradox.'

But another important question now arises: what is the source of the vein filling? In answering this question it must be stated that observations in the field have greatly strengthened the belief of the writer that the chrysotile fibre



A B C D F E F D C B A

Fig. 13.—Sections of seamy parting (natural size) illustrating the successive deposition of mineral matter through segregation. Lot B, Range V, Thetford.

(A) Dark green serpentine, containing specks of chrome iron ore.
(B) Dark blue serpentine, with grains of chrome iron ore on contact line with A.
(C) Whitish asbestiform matter, with fibrous structure vertical to walls.
(D) Layers of pale green serpentine.
(E) Dark blue serpentine with grains of chrome iron ore.
(F) Fine asbestos laces 1-16 and 1-32 of an inch thick.

[1] Report of Geological Congress, 1888

has been formed through segregation of serpentinous matter from the sides of the fissure. In support of this theory it may be mentioned that, a great number of veins—especially those of larger size—have, in the middle, between the two walls, a parting of serpentinous matter and chrome iron ore; that the arrangement of the fibre is at right angles to the sides of the fissure, excepting, of course, those veins which have been disturbed; and that further—and this is the most important proof—some of the veins, in which the process of formation of the asbestos has not been completed, exhibit an arrangement of alternate layers of mineral matter from the sides of the walls similar to metalliferous veins, which frequently contain alternate layers of ore on either side of a central comb of mineral.

In support of the segregation theory the writer may mention that, he has found a seamy parting with a small asbestos vein, in one of the outcrops on lot 13, range V, Thetford, near Robertson station: which shows very clearly that the successive layers of the mineral matter were deposited from aqueous solutions from the walls of serpentine.

The latter, when freshly broken, is of a grass-green colour; seems to be softer than the general run of serpentine, and appears to have undergone considerable crushing movements. Seamy partings running in all directions occur frequently, sometimes containing fine, silky, asbestos fibre, and at other times holding asbestos which has not completed its process of development and formation.

The foregoing discussion of the theories concerning the formation of asbestos fibre, relates only to what was termed on pages 48 and 49, 'vein' fibre; but this does not explain the formation of 'slip' fibre. Observations in the field, however, tend to show that the relation of both varieties seems to be very close: indeed it may be stated that everything affirmed with regard to 'vein' fibre may be cogently applied to 'slip' fibre also. That the class of fibre generally called the 'Broughton' fibre was originally 'vein' fibre, is substantiated by the presence of whole blocks of massive serpentine having regular vein fibre inside the 'slip' fibre zone. On the Tanguay property, lot 13, range VII, Broughton, for instance, the writer observed in a pit 14 feet deep, close to the easterly corner of the lot, massive serpentine, with a series of parallel asbestos veins distributed over a small area 5 by 8 feet. These veins are from $\frac{1}{4}''$ to $\frac{5}{8}''$ thick, delivering a high grade 'crude' fibre, and show no effects of disturbance of any kind. The serpentine itself exhibits no slickensides, joints, or fissures, and seems to have escaped the crushing movement or re-adjusting forces, whose effects are so well displayed in all other pits of that region. On the edges of the massive serpentine, however, a gradual change may be observed: the veins split up, are lacerated, shifted out of their position, and merge gradually into 'slip' fibre; a condition in which almost all asbestos is found in the immediate vicinity.

Further evidence to that effect has been noticed in the pits of the 'Ling Asbestos Company,' and the 'Broughton Asbestos Fibre Company.' As a result of numerous observations in the field, it seems now pretty well established that the peculiarly crushed, and highly slickensided 'slip' fibre serpentine of Brough-

ton is the result of the secondary readjustment, which took place immediately after the crystallization of the fibre in veins. Both rock and veins must have been in a semi-magmatic condition during this period, and pressure may have aided this process of physical alterations of the mass in a marked degree.

No indications are seen in the field to warrant the hypothesis that these magmatic intrusions, and subsequent alterations of the rocks were attended by any great disruptive force; because, if such were the case, the adjacent strata would be all twisted, contorted, and thrust asunder; whereas, as a matter of fact, all rocks accompanying this serpentine belt do not show any effects of violent disrupture; but all correspond to a certain strike and dip, as is pretty well observed on the southerly contact in all the mines of the district. For this reason it appears more reasonable to suppose that, the original rock—olivine—arose quietly from below, increased its volume slowly through hydration, and afterwards went through the stages of alteration above outlined.

Depth of Asbestos Deposits.

'Asbestos found at a depth of 400 feet.' This is the latest important news from the asbestos district, in the Eastern Townships of the Province of Quebec. This intelligence is significant, in virtue of the fact that, the greatest depth of the present asbestos mine workings is about 200 feet. The discovery of asbestos at this greater depth was made as follows:—

When the Black Lake Chrome and Asbestos Company, near Black Lake, had completed the sinking of their shaft to a depth of 400 feet—which shaft had been sunk with a view to exploring their great chrome iron ore body, they ran in a drift passing through a deposit of chromite and serpentine, and finally striking a series of 'asbestos' veins of from $\frac{1}{4}''$ to $\frac{1}{2}''$ thickness: the asbestos being of great silkiness and flexibility. This 'strike,' however, would not be of great general interest, were it not for its bearing on the important economic question in connexion with asbestos deposits.

Before entering into a discussion on this subject, it should be stated that, the question of the permanence and persistency of asbestos deposits is a delicate one. It is a question concerning which few geologists or engineers familiar with existing conditions have as yet ventured an opinion; but from an economic standpoint it is highly desirable that the question of the continuity of asbestos deposits should be given close attention; since the future of a district, which at present is the chief source of the world's supply of asbestos, depends more upon the depth of its known deposits than on the opening of new mines; if, therefore, the writer ventures an opinion on this subject, based primarily on observations in the field, he does so more with a view to stimulate discussion, than to present new and extravagant theories.

To the miner familiar with the mining of minerals other than asbestos, it will appear strange that a district whose history extends back for over thirty years possesses no record of any kind regarding the character of asbestos deposits

[1] Paper read by Fritz Cirkel before the March, 1909, meeting of the Canadian Mining Institute

below a depth of 200 feet. As a matter of fact, there is no visible evidence in any existing asbestos quarry of the extension of the deposits below a depth of 225 feet; and it is no less remarkable that this new discovery was made accidentally, in a mine of another class of mineral. If, however, we consider the methods employed in the exploitation of asbestos quarries, and also the difficulty, or rather impossibility of testing the deposits by diamond drilling, due to the fibrous nature of the rock and mineral, it will be at once apparent, that this lack of knowledge is due to causes arising solely out of the peculiar occurrence of the mineral.

To treat the subject under consideration from a practical standpoint, it will be necessary to consider the results already obtained at the present known depths, and ascertain what deductions, if any, can be made therefrom. In conjunction with this inquiry, reference should also be made to the genesis and structural geology of the deposits, as well as to the character of the formations with which they are associated.

Before a company organized to mine asbestos commences operations, it is necessary to consider such questions as (1) the amount of mineral available; (2) the cost of its extraction; (3) the cost of refining; and (4) the probable profits. These are, of course, considerations common to all branches of mining, irrespective of the character or class of the mineral occurrence. In almost all classes of mining, the methods of exploitation are characterized by the preparation for the stoping or winning of the mineral through shafts and drifts. Exploration by diamond drilling is frequently resorted to, in order to ascertain the value of the property, before any considerable expenditure is made in the installation of costly mining and milling plants. The examining engineer is thus usually enabled to form reasonably accurate conclusions from available data. In asbestos mining, however, the case is different. Here, the extensive, but mostly low grade ore bodies, do not admit of underground working such as is generally employed in mining of other minerals; and in the opinion of the writer, only in the richer asbestos mines can the method of underground mining —as inaugurated at Thetford by Mr. George Smith, the general manager of the 'Bell Asbestos Company'—be followed.

The usual practice is, to start quarrying on a promising spot, and this quarry is gradually widened and deepened as work progresses. In the majority of cases, however, the claims, or undeveloped properties in the district, have nothing more to show than surface outcrops; and only occasionally have pits been opened to depths of, say, 15 to 20 feet, to thus afford some grounds on which to base an estimate of probable value.

The inquiry may then suggest itself: 'why not open up these prospects by sinking shafts on the ore bodies?' The reply to such a query would be that, the very irregular character of asbestos chutes, both in lateral and vertical directions, does not admit of intelligent exploration by deep shafts: for example, if a shaft is started on what is considered an excellent surface showing, it may be expected that immediately beneath the surface a lean chute will be encountered; and if by chance it is found that this lean chute extends vertically for some distance, the conclusion to be drawn from these conditions would certainly not be favour-

able; whereas it is possible, that had this shaft been sunk not over, say, 25 feet away, the results might have been entirely favourable. A striking example of this is afforded by a shaft sunk by the Bell Asbestos Company, twelve years ago, and which was carried down to a depth of 137 feet on the westerly part of this property. The ground penetrated did not pay to work, hence it was concluded that this particular part of the property was of little value. How erroneous this conclusion was, has been demonstrated by the excellent showings exposed throughout the great underground workings at that very part; in fact, the very portion of the property originally condemned has since proved to be, the writer ventures to state, by far the richest asbestos ground over discovered in the district.

But in discussing the question of the depth of asbestos deposits, the only evidence from which we may deduce conclusions is that gathered in the development work so far undertaken in the working mines of the Eastern Townships.

From these operations we have learned the following facts:—

(1) That the asbestos occurs as 'vein' or 'slip' fibre in pay chutes: occurring irregularly in the serpentine; the high grade material alternating with the lean, or with serpentine, poor in asbestos.

(2) That often rich pay chutes are encountered when approaching a granite dike, or near the contact with the schist formation.

(3) That the quality of asbestos found at a depth of 200 feet, or—as in the case of the new discovery above referred to—at the greater depth of approximately 400 feet is the same, or nearly so as that found on the surface.

(4) That wherever there is a large lateral extension of serpentine, and in the latter an asbestos pay chute, the lateral extension of which, on the surface, is more than 100 feet in both directions; this pay chute almost invariably, with occasional interruptions of lean serpentine, continues at depth.

(5) That exploration work by shafts, unless large roomy drifts are run in connexion therewith, is entirely misleading; and in the majority of cases is of doubtful value as a means of developing a property.

Referring to the statement in regard to the lateral extension of the serpentine, it should be emphasized that this is an important factor in determining the continuity of the deposit; since small strips or lodes of serpentine are contaminated and interrupted in their continuity by trap-like portions of the adjacent country rock, which are never expected to be present in an extensive development of serpentine (except granite intrusion) like that of Thetford and Black Lake. As experience has shown, this interruption in the narrow serpentine lodes may sometimes take the form of permanent displacements, and may cut off at increased depth an asbestos deposit, which, on the surface, evinced all the usual characteristics of a pay chute.

The serpentine belt which stretches from range III, Broughton, with a few 'surface' interruptions, through the townships of Broughton and Thetford-Black Lake area, affords great opportunities and scope for the study of the question of the permanence of the asbestos deposits, and the following facts are herewith submitted:—

At the 'Quebec' mine, now 'Ling' Asbestos Company, the fibrous rock, found on the surface in small shallow pits, continued in both a lateral and

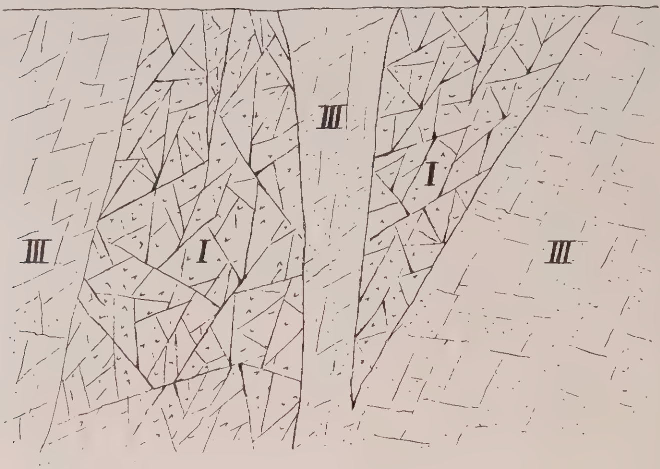


FIG. 14.—Section of seamy parting, showing disposition of mineral matter through segregation.

vertical direction along the contact with the schist formation, and the rock is now mined in a quarry about 300 feet long, 125 feet wide, and 65 feet deep. At the 'Broughton' property the fibrous serpentine, which appeared only in a few

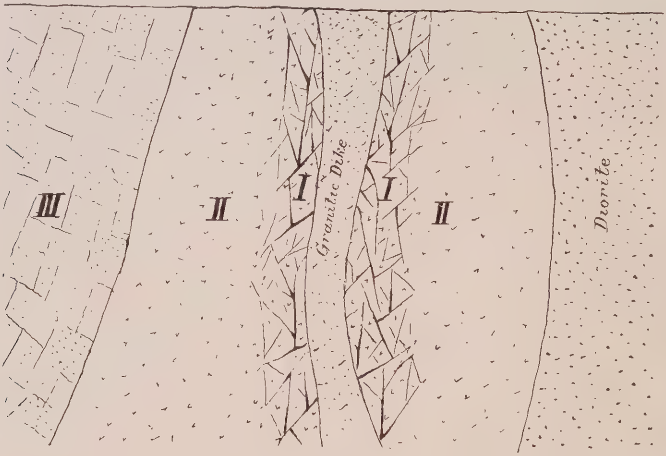


FIG. 15.—Section of seamy parting, showing disposition of mineral matter through segregation.

places on the surface, was found to extend all along the contact, and the quarries are now 85 feet deep. In both cases the fissured and fibrous condition, as

observed on the surface, was found to continue as depth was attained, and although there may, perhaps, be an occasional change in the quantity of the vein

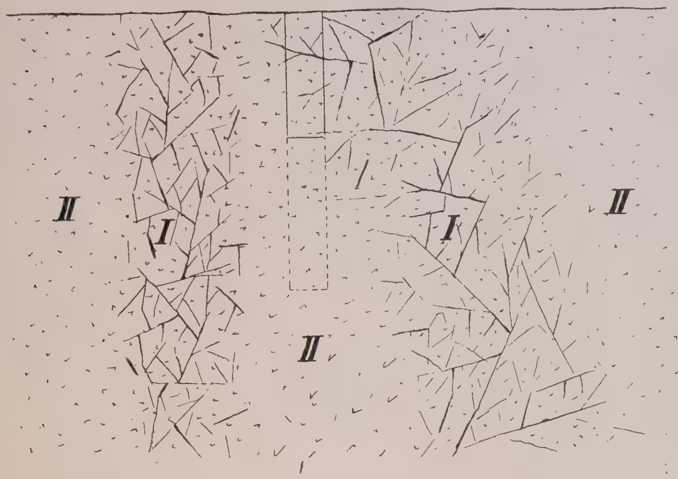


Fig. 16.—Section of seamy parting, showing disposition of mineral matter through segregation.

fibre—as in the case of the 'Broughton'—this does not in any way influence the general conditions in regard to the occurrence at depth in these places.

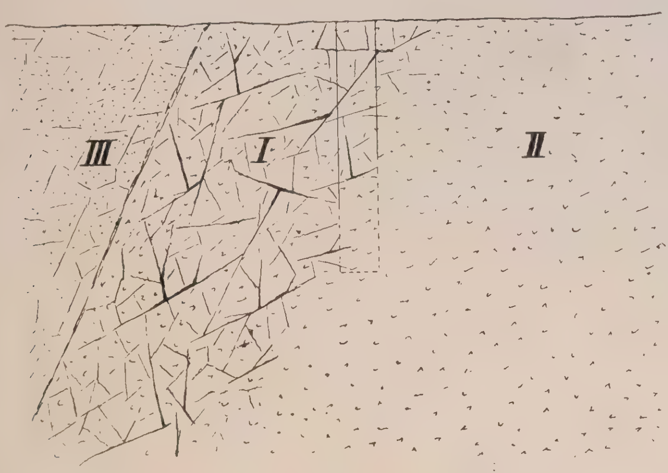


Fig. 17.—Section of seamy parting, showing disposition of mineral matter through segregation.

The great quarries of the 'King,' 'Bell,' 'Johnson,' and 'Beaver' at Thetford, and also the deep quarries of the 'British Canadian,' show conclusively that with depth no marked change in the quality or richness of the asbestos chutes takes

place; indeed, at a depth of 200 feet they appear as continuous and as rich as at any time in the history of these mines; while the new discovery of asbestos at a depth of 400 feet in the shaft of the Black Lake Chrome and Asbestos Company, leads to the conclusion that asbestos deposits are not shallow in their occurrence.

The study of the geological conditions of the district has now fairly well established the fact that the serpentine of the Eastern Townships—the mother rock of chrysotile-asbestos—is a secondary rock. It is the alteration product of olivine (dunite)—a rock mineral of igneous origin. It can be conclusively shown that in nearly all cases this anhydrous olivine rock was changed gradually into serpentine, or a hydrous silicate of magnesia, and that subsequently through the action of certain agencies, fissures were formed and filled with an asbestos-bearing solution, which gave rise to the ultimate crystallization of the fibre.

For the purpose of gaining a better conception of these physical and chemical changes, and their bearing upon the persistency of the deposits, it will be necessary to state briefly their probable causation.

Sterry Hunt[1] shows that the alteration of olivine into serpentine would result in an increase of volume amounting to over 30 per cent. Admitting that some of the silica, or even of the material is lost in the process of hydration, there must have been, at some time, a great expansion in the mass, and this expansion must at the same time have caused increased pressure in the interior of the rock, since, manifestly, the surrounding formation did not allow of an easy expanse through increase in volume. It was thus impossible that fissures could have been formed at this stage of the process.

There seems to be no question that as soon as the process of alteration was finished, a readjustment of the rock-masses took place, and this readjustment resulted in the formation of joints and slickensides, such as we find in the quarries to-day; and not as is generally supposed in the formation of fissures. This theory is substantiated by the fact that, in the quarries at Thetford, numerous places can be seen where these fissures (asbestos veins) cross directly through joints and slickensides. The next question is, how have these fissures been formed? Was it through shrinkage due to a loss in silica, or due to shrinkage of the rock-mass through cooling? Now, if these fissures were formed through the loss of silica, they would have been formed during the process of alteration, that is, before the joints and slickensides were formed, but the impossibility of this is shown above.

The most rational explanation, and the one which seems to gain the most support is, that the formation of cracks is caused through cooling and shrinkage of the rock-masses similar to the formation of cracks through shrinkage of a gelatinous mass of iron carbonate in the so-called septarian nodules of clay ironstone, as suggested by Merrill. However, it is also probable that the intrusion of the granite dikes so frequently met with in the serpentine masses has caused or facilitated to a great extent the formation of numerous fissures in the immediate proximity of these intrusions, by rapid dehydration through the agency of

[1] Mineral Physiology and Physiography, page 506.

heat. The fact that very frequently an accumulation of asbestos veins can be noticed when approaching these intrusive dikes seems to substantiate this theory.

It is obvious from a geological point of view, that all these radical changes, which were perhaps brought about during long geological intervals, took place not only on, or near the surface, but also in depth; it is impossible to imagine that the changes in the character of the rock, namely, the alteration into serpentine; the subsequent readjustment of the rock; the forming of fissures; and the ultimate filling of the latter with a crystallization of the serpentine solution should have been confined only to rock portions near the surface, hence we are justified in assuming that these changes must have affected the whole system; that is, they must have extended to great depth; for we cannot conceive of any influence coming from the surface, or being exerted near the latter, which could have evolved such conditions.

There exists a great difference in the quality of serpentine and the fibre found in the Thetford and in the Broughton district: and much interest is being manifested, at present, in the question as to the relation, if any, between the two occurrences. Recent investigations have shown—and this is amply supported by the discoveries which have been made during the last year or two—that the Broughton serpentine belt, although frequently interrupted in its course in the townships of Broughton and Thetford, has some connexion with the big Thetford-Black Lake serpentine hills; and further, that a gradual change can be noticed in the 'slip' fibre quality of the asbestos found at Broughton to the 'vein' fibre quality as found in the westerly part of Thetford.

This, evidently, goes to show that there exists a genetic relationship between the two occurrences; indeed, it seems very probable that the serpentine belt, throughout its extent, has its origin in one common source; but that at Broughton, where the 'slip' asbestos fibre is produced, additional changes and readjustments have brought about the prevailing conditions. In order to make this clearer a first attempt has been made by the writer to tabulate the successive changes which the original rock in all probability underwent.

Broughton.

Thetford. Black Lake.

(1) Intrusion of olivine (dunite) through the earth crust from below.

(2) Gradual alteration of the rock to serpentine through hydration, and perhaps loss of silica, increase in volume.

(3) Slow readjustment of the rock-masses, resulting in the formation of joints and slickensides.

(4) Subsequent formation of fissures as receptacles for asbestos fibre, through shrinkage of the rock, and also through injection of granite dikes.

(5) Infiltration of serpentinous solution from the sides of the wall through process of segregation, and subsequent slow crystallization of chrysotile.

(6) Second slow readjustment of the magmatic rock-mass, and formation of 'slip' fibre.

The writer has gone more fully into the question of origin than he at first intended; but this was deemed necessary in order to follow step by step the altera-

tion and successive changes of the original rock-mass, and also to snow that these most radical changes must have affected the serpentine not only near the surface but also to a considerable depth.

To what depth these rock-masses have been affected by all these changes, in order to produce what is known as asbestos rock, must remain a matter of surmise; but, judging from the results which have been set forth, I venture the opinion that these workable asbestos deposits extend to considerable depth, probably to several thousand feet.

Mr. John A. Dresser[1] expresses himself as follows on the subject of depth of asbestos deposits:—

> 'The question of the depth of asbestos deposits in the Eastern Townships depends in a large degree for its solution on the form taken by the eruptive rock from which the serpentine has been derived. This has not yet been satisfactorily determined. The form may have been a sheet or laccolith, intruded between beds of older rock. In that case the sheet would be more or less nearly horizontal in position, and would not have reached the surface until it was uncovered by the erosion of the overlying beds.
>
> 'Or it may have been an intrusive mass of rock—which was brought to the surface and has since had its upper portions removed by erosion.
>
> 'In the former case the depth of the asbestos would necessarily be limited by the thickness of the intruded sheet, but in the latter case, the serpentine, and consequently the asbestos, might continue to an indefinite depth.
>
> 'The other factors necessary to the occurrence of asbestos are the segregation of olivine in the original rock, and the alteration of the olivine to serpentine. Of the first it may be said that olivine is a mineral characteristic of the lowest known depths of the earth's crust; and of the second, that serpentinization is a deep-seated process, which, unlike weathering, does not depend on the action of the atmosphere to produce it.
>
> 'Therefore, except for the possibility of reaching the floor of a sheet, it seems safe to conclude that the asbestos deposits of the Eastern Townships will continue for as great a depth as they can be profitably mined.'

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[1] Trans. Canadian Mining Institute, Vol. XII, 1909, page 203.

CHAPTER III.

QUARRYING OF ASBESTOS.

The work of extracting the asbestos from the rock in which it occurs, and converting it into a saleable article, will be described under the following heads:—

(1) The quarrying proper, that is, the blasting, separating the dead from the useful material, hoisting the same from the pits, and transporting it to the cobbing sheds or mills.

(2) The cobbing or dressing of the better qualities, that is, the separation of the fibre by hand from the adhering rock particles; together with the mechanical treatment, in mills, of all rock or fine material containing fibre; grading of products; and subsequent transportation of product over railways, and by shipping to the markets of the world.

It is important that all the different stages through which asbestos has to pass until it is a finished product, be treated separately; since these involve the entire expenditure from the winning of the crude material in the rock, up to final delivery to the consumer. The success of a quarry depends to a very large extent upon not only the peculiar qualities of the mineral, and the mode of its occurrence—which differs so widely from those of any other known mineral—but also upon careful, economic, and intelligent direction of the various operations enumerated.

Advantages and Disadvantages of Open-cast Work.

Nearly all the companies employ the method of open-cast work as the means for exploitation of asbestos deposits; for in spite of all its disadvantages—especially in severe winter weather—it has proved itself to be the most convenient and cheapest method hitherto employed. Its advantages over underground work may be summarized thus:—

(1) Easier supervision.
(2) No trouble as regards ventilation, the men are always working in the open air.
(3) Easier lay out of works in larger steps and stopes than is usually possible in underground works.
(4) No timbering is necessary.
(5) Complete extraction of all the asbestos encountered in the rock; no loss in the form of pillars.

The principal disadvantages of open-cast work are:—

(1) The removal of all the waste rock resulting from dikes and barren zones of serpentine.
(2) Exposure of men to the inclemency of the weather: work is interfered with; amount of work done reduced considerably; or even stopped by bad weather: such as heavy rain, snow, or extreme cold, etc.
(3) Curtailment of dumping ground on properties of limited extent.

However, recent experience in a prominent quarry at Thetford seems to demonstrate that open-cast work, under certain conditions, may be replaced by regular underground methods: and although all the difficulties in connexion with their general application—such as we are accustomed to find in lode mining—are not wholly overcome, it seems reasonable to assume, that before long, the larger and richer mines, at least, may follow suit.

The question of underground mining has been taken up spasmodically by different companies in the district. At the 'Union' quarry, some twenty years ago, a somewhat extensive tunnel was run during the winter from the foot of a hill, and a shaft sunk in connexion with the same; but the facts, as regards the results, are not definitely known. In the old Broughton (Fraser) mine a shaft was sunk to a depth of 100 feet along an excellent asbestos vein near the contact with the slate formation, and it is reported that the results were satisfactory for the first 75 feet; but owing to the irregular character of the vein below that depth, work had to be abandoned. Seven years ago, the Bell Asbestos Company, sunk at Thetford a roomy shaft in the western part of the property close to the King quarry; but this experiment was not successful, since the shaft went through an apparently barren zone, and little hope was entertained as to finding better conditions in the immediate environment.

For a long period after this experience, underground work was looked upon in the district as an impossibility. It was affirmed in support of this contention that, the asbestos pay chutes were distributed in a very irregular fashion, indeed so irregularly that no economic system could be brought into operation; and, moreover, that due to this cause also, valuable ground, or perhaps pillars composed entirely of valuable deposits, would have to be sacrificed for the sake of safety. It was further maintained, that on account of the highly slippery condition of the serpentine, only narrow drifts could be run; otherwise a great amount of timber would be necessitated in order to support the ground so penetrated, and that in consequence of this, the cost of extraction per ton of ore would be excessive. The underground work, however, inaugurated and successfully carried on by Mr. Geo. Smith, M.E., at the Bell quarries, seems to demonstrate that not all of the contentions hitherto brought forward can be substantiated; indeed it has been shown, that after all not so much timber is used, in spite of the fact that all the drifts are very large, much larger than in any other class of underground mining. Further, the question of valuable pillars for the purpose of safety may be regulated to satisfaction, since the running of a system of approximately parallel drifts in different levels, admits of a thorough study of the ground preparatory to the winning of the mineral proper. As to the employment of timber in the drifts, it may here be stated, that the total length of underground work in the mines of the Bell Asbestos Company, is now 1½ miles, and the writer, who inspected these drifts twice, noticed very little in any of them. No accidents caused by a falling roof have occurred so far, for a rigid inspection is made almost daily of all the workings. With increasing depth, however, conditions in that direction will probably materially change; the rock pressure will increase, necessitating, perhaps, heavy timbering, where to-day nothing of the kind is required.

Large quarry of the British Canadian (Amalgamated Asbestos Corporation), Black Lake, Que.

The great advantage of this mining method over quarry work is the convenience with which the work can be carried on during the winter. In open works, to win the asbestos through ice and snow, and sometimes very cold weather, reduces enormously the working results; the drying of the ore, which is mixed most of the time with snow and ice, requires almost three times the amount of fuel needed at ordinary times; while the transmission of compressed air, and more especially steam, to the pit bottom, has its great difficulties. For this reason it is questionable whether it pays at all to work some of the quarries in severe winter season. As a matter of fact, if prices are not specially tempting, a number of them close down altogether.

One of the greatest hindrances in the way of economic open quarry work is the selection of a suitable dumping ground. Many mines which have little ground at their disposal, find considerable difficulty in solving this problem. In the early days of asbestos quarrying, when very little engineering skill was displayed, and little thought was given to projected efficiency, most of the dumps were placed quite close to the quarry, as was the case in most instances. This accumulated waste rock had to be removed, when it was found that the ground so covered contained large asbestos-bearing zones. To-day—in some of the quarries on ground specially bought for that purpose—long, horizontal, gravity tramways are built to remove the dumps as far away as possible.

The question of the disposition of the dumps is daily becoming of increasing importance; in fact some of the companies which formerly treated this subject as a secondary matter are beginning to give it earnest attention; they find out that they are cramped for room, and that large amounts of money must be spent to relieve the situation: in order to secure a continuation of the works on the lines already adopted.

In underground mining excellent facilities for the placing of dead rock are afforded; since a system similar to the methods employed in wide lode mining may be introduced, whereby stopes can be filled conveniently with the debris. This would also secure safety against unexpected caveins, and would, in addition, greatly increase the general working economy of the mine.

However, taking into consideration all the advantages of both methods, together with their disadvantages, it must be said that the open quarry method remains the favourite of the miner, and will, doubtless, be retained as long as circumstances permit. Moreover, there seems to be no doubt that the application of the underground method—as introduced by Mr. Geo. Smith—will be confined only to such mines as work on approved rich ground, and the practical working sphere of which permits of gradual expansion. It will thus be seen, that in future the probability is, that the richer mines may employ the combined quarry and underground method: the one preferably for the summer season, and the other for the winter. Additional details regarding the underground system, as used by the Bell Asbestos Company, will be found on page 188.

Removal of Overburden.

The first operation in opening a quarry is, the removal of the soil which covers most of the asbestos-bearing areas, which varies in thickness from a few

feet up to 25 feet. In Black Lake, the crest and slope of the large serpentine ridge is for the greater part covered with a thin layer of humus, thus rendering prospecting work comparatively easy; the lower ground of this locality, however —the area between Black Lake and Thetford—is covered to considerable depth with soil, while at Thetford, the thickness of the overlying soil is, in some places, 15 to 20 feet. The removal of this soil for open quarry work is performed only in the summer time; the winter, on account of frost and snow, being too severe for this class of work.

The soil is generally cleared off with pick and shovel, and loaded into large dumping cars on trucks which are laid for this special purpose close to the work, and shifted when required.

Several of the larger Thetford companies employ steam shovels for this purpose: thus bringing down the cost of moving a cubic yard of soil to a minimum.

Quarry Work.

As a rule the quarries in the smaller mines have a very irregular shape: most of them following the trend of the asbestos-bearing zones; while the lean serpentine, or intrusive dikes are left as pillars. In the larger mines, however, where the locations of the asbestos-bearing and lean rock, and the location and extent of intrusive dikes have for years been more fully studied, the quarries have, generally, a more regular outline: as at the King, and Bell pits, Thetford; also at the large quarry in Danville.

FIG. 18.—Section of King Bros.' large quarry at Thetford.

At these quarries, no discrimination has been made between dikes, lean or rich portions of the serpentine; no pillars of any rock have been left, for the reason that these would only prevent mining with advantage towards depth. The shape of the quarries is rectangular: and while the outlines of the walls are not strictly in conformity with that shape, nevertheless the execution and the progress of the work in the pits indicates that, a definite system has been followed in late years. The principal advantage of the system employed in these mines lies in the fact that, generally, a number of different zones—both lean and asbestos-bearing—are thus laid open, hence the work, also the supply of the ore, can be regulated to better advantage according to requirements.

As a general rule, in all the larger pits the rock is taken down in a series of benches, stopes, and terraces, which vary in dimensions according to the size of each pit. A good illustration of systematic progress in quarry work is the long pit of the King quarry of the 'Amalgamated Asbestos Corporation,' at Thetford. This pit has a length of 1,350 feet, and an approximate average width of 350 feet. The height of the benches and stopes varies from 5 to 30 and 40

feet in the deepest part; while the length of the terraces varies between 50 and 250 feet.

Explosives.

The great bulk of the dynamite used in the asbestos quarries contains 40 per cent of nitroglycerine; the cartridges being, as a rule, 8″ long, by 1¼″ diameter, and are packed in boxes of 50 pounds, containing from 85 to 95 cartridges. The price is from 14 to 15 cents per pound.

Effect and Cost of Hand-drilling.

Hand-drilling is still in use in the smaller quarries and prospects, also for block-holing.

As a rule, three men are employed with 1″ octagonal steel, and six or seven pound hammers. The average capacity in hard serpentine or granite is from 15 to 18 feet per shift; and the cost per foot—including explosives—from 24 to 28 cents. In some of the mines block-holing is done by one man only: using ¾″ steel, and three to four pound, short handled hammers. The capacity is from 7 to 9 feet per day, and the cost—including explosives—about 20 cents per foot.

Effect and Cost of Machine-drilling.

In nearly all the quarries, machine-drilling is in vogue for the breaking of the rock *in situ*. The proper placing of the bore-holes is a very important factor in obtaining the best results from blasting in asbestos rock. To do this, it is necessary that the operator has a thorough knowledge of the position of the strata, and the position and trend of cracks and fissures. To obtain this knowledge the intelligent miner examines the rock attentively, and carefully ascertains for each blast the position of any joints and fissures in the rock; to enable him to form a judgment as to the proper direction to be given to the bore-hole, and the free sides available for the best results; but it happens, too often, that two miners will have different opinions as to the proper charge for a certain shot. The result is, very frequently, a waste of explosives, which sometimes assumes considerable proportions. Where the rock is massive, and the walls of the benches to be taken down vertical, the direction of the holes is vertical, or nearly so; and when the rock is much fissured, the holes have, generally, an inclined position according to the largest fissures and the bulk of the rock to be taken down.

When blasting benches having several free sides, the bore-holes are arranged in rows, and they are as nearly as possible parallel with the largest free side, so as to obtain the deepest bore-hole, and thus be able to use, relatively, the smallest quantity of explosives. In order that the charge may be as fully utilized as possible, due regard is given to the contour of the free sides and the longest line of resistance. The bore-holes in this case are generally made vertical, so that the explosion will not have to lift the rock it breaks down, but will allow it to fall by itself, and thus give less work afterwards in removing.

The depth of holes ranges between 8 and 10 feet, and in the case of exceptionally large faces, 12 and 15 feet. The charges of the drill holes vary, of

course, according to the position of the latter, quality and quantity of rock as outlined above; but, as a general rule, in the course of ordinary work—where the faces are free on one side—from 0·45 to 0·5 pound of dynamite are used for every foot drilled.

The rock drills in use are mostly of the Ingersoll and Rand types, with $3\frac{1}{8}''$ cylinder, and a stroke of $6\frac{3}{4}''$.

Electric Drills.

Lately, electric percussion drills have come into use; but many improvements will have to be made on the present design before their use will become general. Most of the manufacturers have adopted the following method: power is conveyed from an electric motor—which is placed either on the drill carriage, or in a box lying on the floor—to the drill by a flexible shaft. Compression springs are placed in the rear of the carriage; the drill carriage being released when the springs have been compressed to a certain pressure, and the drill is thrown forward by the force of the expanding springs. There are springs in front of the carriage also, which force the drill back after the blow has been struck; and there is the usual shifting arrangement, which comes into operation as the drill returns; by means of which, rotation is effected. In another form of drill—known as the box drill—air is compressed inside a cylinder forming the drill carriage: the drill being held in front and working in guides as usual, while the compression of the air is accomplished by an electric motor attached to the back of the drill.

In another percussion drill the following principle has been introduced: motion is communicated to the drill by means of a solid plunger, around which two coils of wire are fixed; electric currents passing through the coils. The plunger is pulled back by the current passing into one coil, which, in receding, compresses a strong spiral spring in the rear. It is forced forward by the current in the other coil, aided by the force of the expanding spiral spring.

The use of electric drills in the asbestos quarries has several advantages over those actuated by steam or compressed air: especially in the winter time; since there is no loss through transmission, and the working effects are generally much higher.

For block-holing, little giant drills are used: the diameter of the piston is only $1\frac{7}{8}''$, length of stroke $3\frac{5}{8}''$, and depth of the holes drilled from 1 to 2 feet.

The steel usually employed is octagonal in shape, $1\frac{1}{8}''$ in diameter for the larger, and $\frac{5}{8}''$ for the smaller drills. In starting, a short, steel, primary drill called the starter is used, and when this reaches its limit, a longer piece is substituted; this is followed by a still longer piece, and the process continued until the desired depth of the hole is reached.

The diameter of the hole at the beginning made by the starter is, for the larger machine, $2\frac{3}{8}''$; which is gradually reduced by using successively, steel of smaller diameter—$1\frac{1}{8}''$, at a depth of 10 feet. As a rule, two sets of steel are provided for each machine; so that one set may be sharpened while the other is being used.

The motive power for actuating rock drills is usually compressed air, or steam; but in utilizing the latter, there is a large loss from condensation in transmitting steam from boilers to the drills: especially in the usually severe winter seasons, when all the main pipes require to be covered with insulating material, which entails extra cost.

Compressed air has a great advantage over steam: the loss in transmission is small, hence the amount of drilling done is comparatively high. The operating results with steam drills are from 40 to 45 feet, per shift of ten hours. The total cost per foot—including power, labour, and explosives, at present prices of fuel—is from 15 to 18 cents; not including, however, wear and tear of machinery and interest on capital involved.

In nearly all the quarries the firing of shots is performed by means of electric batteries. There are a few instances where one-hole blasting is still in vogue. In support of this practice it is urged that not alone is a saving of explosives effected, but that the expense of picking them up is less; because the asbestos veins are less liable to be smashed to small fragments, and widely scattered.

The expenditure for explosives per ton of rock broken, in mines where the rock is of a solid, massive character, is 3⅗ cents per ton; in mines where the rock is much fissured and shattered, as in the East Broughton mines, the cost is a little less.

Each pound of dynamite brings down, on the average, from 4·25 to 5 tons of rock.

Separation and Removal of Rock and Ore.

After the firing of shots, the broken material undergoes a hand-sorting process; which is different in every quarry, according to the grades to be produced, and the ground worked. Where no crude or hand-cobbed fibre is produced, all the rock containing fibre, together with the fines scattered all over the pit, is sent to the mill; but in quarries where the different qualities of crude are produced, the material to be treated comprises:—

(1) The long asbestos fibre, and pieces of rock containing the same.
(2) The milling material, or rock, containing the shorter fibre.
(3) Fine material, and the scrapings of the pits resulting from blasting and breaking up the rock by means of sledge hammers.
(4) Dead rock.

The material specified in No. 1 is sent to the cobbing sheds, and the material indicated in Nos. 2 and 3 is sent to the mill: the fines going first, however, to the dryer.

If the bottom of the quarry is on the same level as the top of the dump, the removal of the debris is simple: the latter is loaded directly into dumping cars, or on a platform, and subsequently placed, by means of a small derrick, on trucks, and then delivered to its destination; but in most cases where deep mining is going on heavy boom and cable derricks are employed.

Construction of Boom Derricks.

Boom derricks are employed in only a few of the smaller mines, or where dumps have to be worked over again. Quarries of large dimensions do not, generally, admit of the successful application of boom derricks; on account of their very limited working radius.

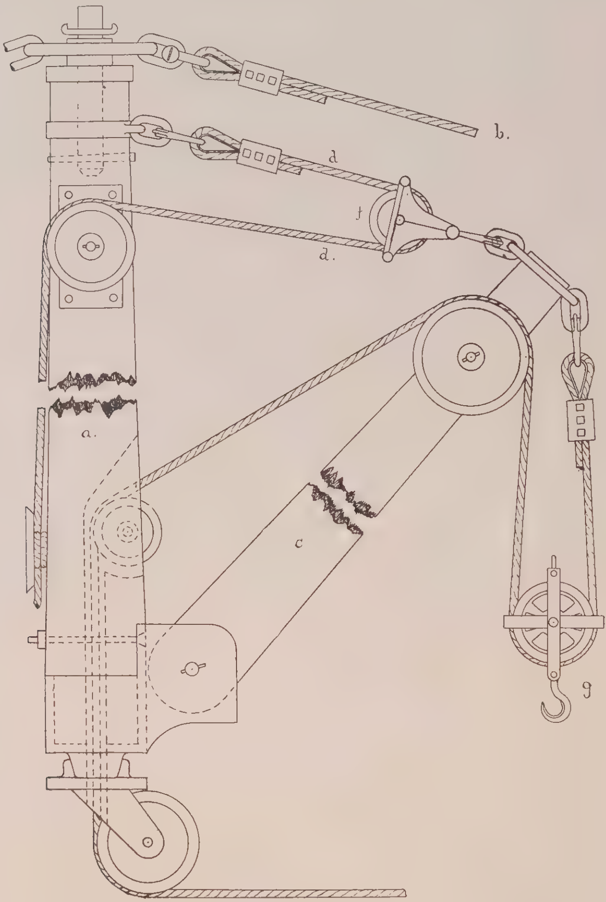


FIG. 19—Boom derrick.

A boom derrick (Fig. 19) consists of a mast held in a vertical position by means of guy ropes or legs. To provide for the rotation of the mast about its vertical axis, the lower end of it is pivoted into a socket of the fixed bed-plate. A boom or arm is hinged to the foot of the mast immediately above the pivot. The farther end of the boom, which carries the load, is suspended from the top

Typical construction of cable tower.

of the mast by ropes, which pass over pulleys to permit the variation of the inclination of the boom to the mast. The length of the boom is from 30 to 50 feet; its working radius is naturally limited and can hardly be extended more than 50 feet.

Construction of Cable Derricks.

A cable stretched from the top of a well guyed frame or mast to some point across the working pit, along which the load is to be transferred, constitutes the main feature upon which the cable-derrick is constructed. A carrier suspended from the cable by a system of pulleys travels along the cable, and may be arrested, lowered to pick up the load, and rehoisted at any point between the limits of the cable. In this manner the load is transported along the cable.

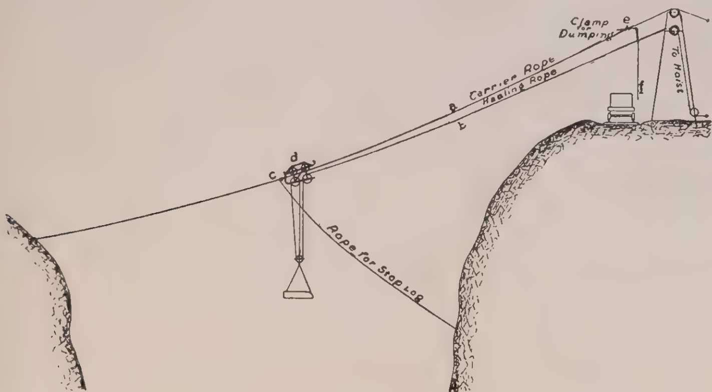


Fig. 20—Incline cable hoisting plant.

The cables may span a distance of 400 feet, are made of crucible steel, and are from $1\frac{1}{2}''$ to $2''$ diameter: depending on the length of the span and load to be carried. The ropes for hoisting are from $\frac{5}{8}''$ to $\frac{3}{4}''$ diameter.

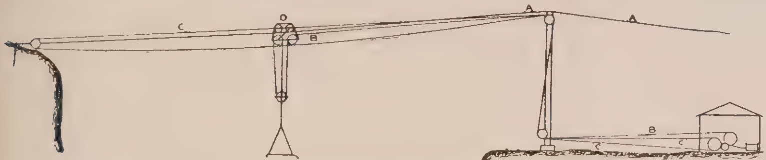


Fig. 21—Horizontal cable hoisting plant.

The cable ways may be either inclined (Fig. 20) or horizontal (Fig. 21). In the case of the inclined cable way the carrier is provided usually with one rope: the fall rope, which is also used as a hauling rope. To prevent the carrier moving along the cable when the load is raised, it is necessary that the angle of inclination of the cable be at least 30°, to render the component of the force of gravity of the load acting down the cable of sufficient intensity to retain the carriage in position until the load arrives at the stop on the cable.

On stopping the carriage at any point on its upward journey, the load may be lowered and dumped, after which the carriage returns down the incline to the stop. It is generally necessary, however, to provide a bridle or link, (*e*), pivoted to a wooden clamp on the carrier rope over the dumping point, which link is raised by a cord, (*f*), and dropped over the hook on the end of the carriage before dumping, and afterwards released to allow the carriage to return.

To obtain control of the carriage so that a load may be picked up or lowered at any point on the line, without shifting the stops on the carrier rope, a third rope or extra hauling or tail rope, $\frac{3}{8}''$ diameter, is required; which is attached to the carriage and wound in at the same speed as the fall rope after the load has been lifted, and by means of which the carriage may be restrained in its movement down the incline on the return trip, or made to stop over any point in its range of travel for loading or unloading purposes.

By making the hauling rope endless: that is, by passing it from the carriage around the separate winding drum on the hoist and around a sheave on the farthest end of the cable way, the latter may be used in a horizontal, instead of inclined position. In some quarries the inclined, and in others, horizontal cable-ways, with tail rope are utilized. Miners generally prefer the horizontal to the inclined cable-ways, on account of the ease with which the carriage may be stopped at any desired point from the hoist; while with the inclined cable-way a constant shifting of the stopping log on the cable rope is necessary.

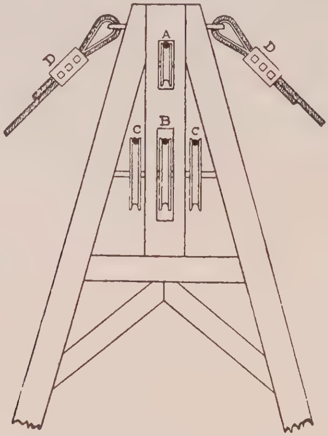


Fig. 22.—Two-leg support for cable derrick.

(A) Carrier rope. (C) Hauling ropes.
(B) Lifting rope. (D) Guy ropes.

The support for the cable consists either of a pyramid, constructed of four legs fitted and bolted securely; or of two legs held in vertical position by $\frac{7}{8}''$ guy ropes arranged in the manner illustrated in Fig. 22. On the top of these supports are placed the sheaves for the carrier and haul rope. It is claimed for the pyramid-shaped supports that they are very rigid, and strong, and do not

require any guy ropes; while the two leg supports are of simpler construction and can be more easily removed.

Single mast supports were perceived in one mine; but they are exceptions to the general rule.

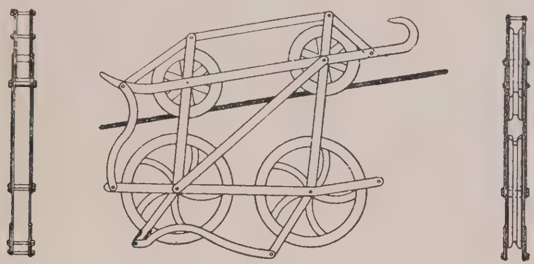


FIG. 23.--Carrier for cable hoisting.

The cable carriage (Fig. 23) is substantially constructed of wrought iron, and is yet comparatively light. The running wheels are of cast iron, have flanges, and, as a rule, are provided with anti-friction bearings. The hoisting wheels are of cast iron, 18″ to 24″ diameter, in order to reduce the wear on the hoisting rope, and to enable the gin block to lower as freely as possible.

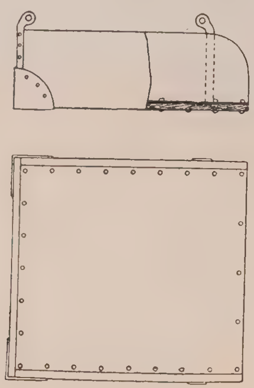


FIG. 24.—Construction of transport boxes.

The boxes for hoisting are made of 2″ hardwood, and hold, generally, between 16 to 20 cubic feet of rock, weighing from 2,200 to 2,500 pounds. The bottom is covered with ¼″ steel plate; while in some quarries the outside corners are covered and protected by heavy flanges (Fig. 24). It is claimed that a box of the above construction in ordinary work does not last longer than from six to eight months. One company has attempted to use boxes made of iron; but it appears that the experiment was not successful.

The heavy cable is fastened at both ends, either to a system of heavy wooden legs loaded with stones (Fig. 25), or to a large iron bar securely fastened in a drill hole in the solid rock.

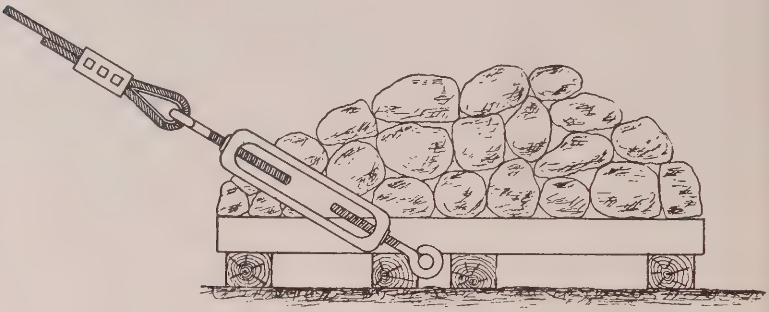


FIG. 25.—Anchorage of carrier rope.

For the purpose of stretching the cable from time to time a turnbuckle is inserted at one end of the cable, in the manner illustrated in Fig. 25.

Hoisting Engines.

All hoists used in the district are of the double cylinder type, with reversible friction drums.

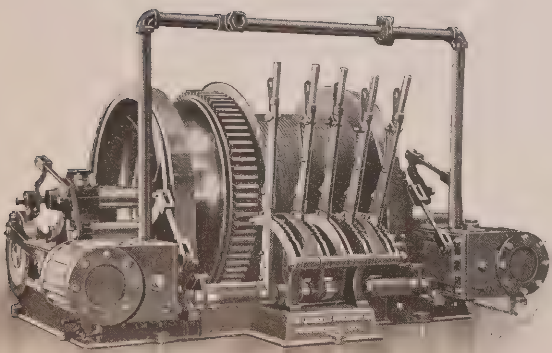
In boom and inclined cable derricks one drum hoist is sufficient; while cable derricks with tail-ropes require two drums. The newest type of a cable-way hoist is shown in Plate XXXVI. This hoist has friction drums mounted on one axle, with brakes worked by hand lever and link motion; the narrow and curved drum serving for the endless tail rope.

This hoist is called the special cable-way engine, and on account of its simple construction is lower in price than the engines with separate drums, hence is replacing the latter everywhere.

Efficiency of Hoisting Plants.

The number of tons of rock which can be raised from a quarry by means of a cable derrick depends upon the depth of the pit, the distance to be hauled, and the capacity of the machinery. As a rule, however, the distance in nearly all the quarries does not exceed 400 feet; while the greatest depth so far attained is 185 feet. Taking these figures as a basis, and assuming the load to be one ton, and the capacity of the hoist 40 horse-power, an average of from 240 to 300 tons can be raised in a ten hour shift. It must be understood though, that a cable derrick is used also for other purposes: for instance, the lifting and shifting of heavy pieces of rock in the quarry in order to clear the working face after blasting. On account of the work entailed through the separation of the useful from the dead material in the bottom of the pit, a cable derrick is very seldom used to its full capacity. In order, therefore, to provide for a steady supply of ore in all the quarries, a larger number of cable derricks than the regular output

PLATE XXXVI.



Jenckes cable hoist.

capacity indicates, are employed and stationed along the quarries. In illustration of this, it may be cited that one company treating about 300 tons of asbestos rock in the mill and raising for this purpose as an average 500 tons, has employed eight cable derricks.

Haulage and Dumping.

The dumping cars in use are of two classes: (1) those hauled by men or by horses, and (2) those hauled by power. Dumping cars of the first class consist of a truck and a movable box, constructed for a 23″ gauge, and holding from one-half to one ton.

The box cars for power haulage hold from three to six tons of rock. They are furnished with brakes and such mechanism as will permit the tilting of the box to both sides of the track.

The gauge of the latter is 42″. In all the larger quarries haulage is being done by small 10 and 12 ton locomotives; and it is claimed that not only is the cost of transport per ton considerably reduced, but that accidents are very few. The first introduction of these small locomotives was made by Mr. George Smith, in 1895, who used in their construction two cylinders from an old hoisting engine, in connexion with gearing motion. The experiment was successful from the start, and since that time most of the larger mines have been using this class of locomotives. The main advantage of these geared locomotives is the great ease with which very sharp curves are taken; while their general construction is such as to reduce all repairs to a minimum. It is claimed that in some of the mines each locomotive makes from 50 to 60 miles a day. The diameter of the cylinders is 8″, with 10″ stroke. The engine is fitted with steel frame, saddle tank, and steam brake.

The steel rails employed are of either 19 pounds to the yard, for light dumping cars; or 45 pounds, for mechanical haulage.

General Hoisting and Hauling Arrangement and Position of Cable Derricks.

The position of the cable derricks is determined by the location and number of working points in the pit, and changes with the shifting of operations. Where the quarry is of rectangular shape, all the supports and hoisting engines are, as a rule, placed on one side of the pit; the former usually all on one row near the border of the pit, leaving, however, enough space for the passage of dumping cars. A good illustration of this arrangement is the large 'King' pit of the Amalgamated Asbestos Corporation at Thetford. The derricks employed here are all of the tail-rope type; the cables being stretched nearly parallel at fixed intervals over the pit; while all the hoists—some of them are grouped together in one building—are stationed back of the supports.

In cases where the pits have an irregular shape, and curved outline, an effort is generally made to place the hoists and supports on one central spot, from whence all the cable-ways can be operated.

The tracks for the haulage of dumping cars are generally laid alongside, and close to the borders of the quarries. Generally, two tracks are close to each other; one for the loaded and the other for the empty cars.

In some of the mines the tracks are of an ascending grade towards the pit; allowing the loaded cars to descend by gravity for some distance to a shunting yard, where they are sorted and delivered to their destination.

An ingenious device for the disposal of the mill rock from the pits, the only one of its kind in the district, has been installed at the quarries of the 'Jacobs Asbestos Mining Company,' of Thetford. (See Plate XXXVII). Here the boxes coming from the pits by way of cable derricks are dumped into a system of ore pockets which empty into a pan conveyer below. The latter transports the ore directly to the ore bin of the mill. There are altogether installed 7 cable derricks with as many ore pockets. The conveyer has a total length of 325 feet, and consists of heavy steel pans 30″ wide, each pan being reinforced by angle iron. Its velocity is 40 feet per minute.

The signalling from the pits to the hoists in shallow workings is effected by shouting; but where the pits are deep, and where the operations cannot be noticed by the engineer, boys are stationed at points of vantage on the border of the pit, who convey the signals either by electric bells or by means of a galvanized wire to a hammer which strikes a bell, the number of strokes indicating what is required.

Each engineer stationed at a hoisting engine marks the number of box loads he has hoisted during the shift, and the summary report of all the hoisting engineers' records must tally with the number of cars delivered at the different stations; i.e., at the cobbing shed, the dryer, the mill, and the dumping ground.

Recent Improvements in Hoisting Appliances.

The suspended cable—which replaces the boom derrick in all cases where a wider range of operations is required—with its travelling, hoisting, and propelling lines, possesses many advantages. First of all, the main cable, suspended high over the quarry from the terminal towers, provides a roadway entirely independent of obstructions and of the condition of the surface. Having no other supports than those provided at the terminals, it has one clear span, hence there is no interference with the passage of trains, waggons, or other work carried on within the range. With a suitable equipment in the way of engine, sheaves, carriers, and skips, almost any kind of hoisting may be carried on with a certain amount of speed, and over a comparatively large range. It comes here in direct and successful competition with the boom derrick; for it does the same work with a substantial saving in operating expenses. Upon watching closely the operations of these cable derricks, however, we find that they also have their serious drawbacks: and this is more apparent the greater the quantity of low grade material handled. In order to work simultaneously at many points in a big quarry it is necessary to install quite a number of these cable-ways. In one

Arrangement of cable supports at King's quarry of the Amalgamated Asbestos Corporation, Thetford, Que.

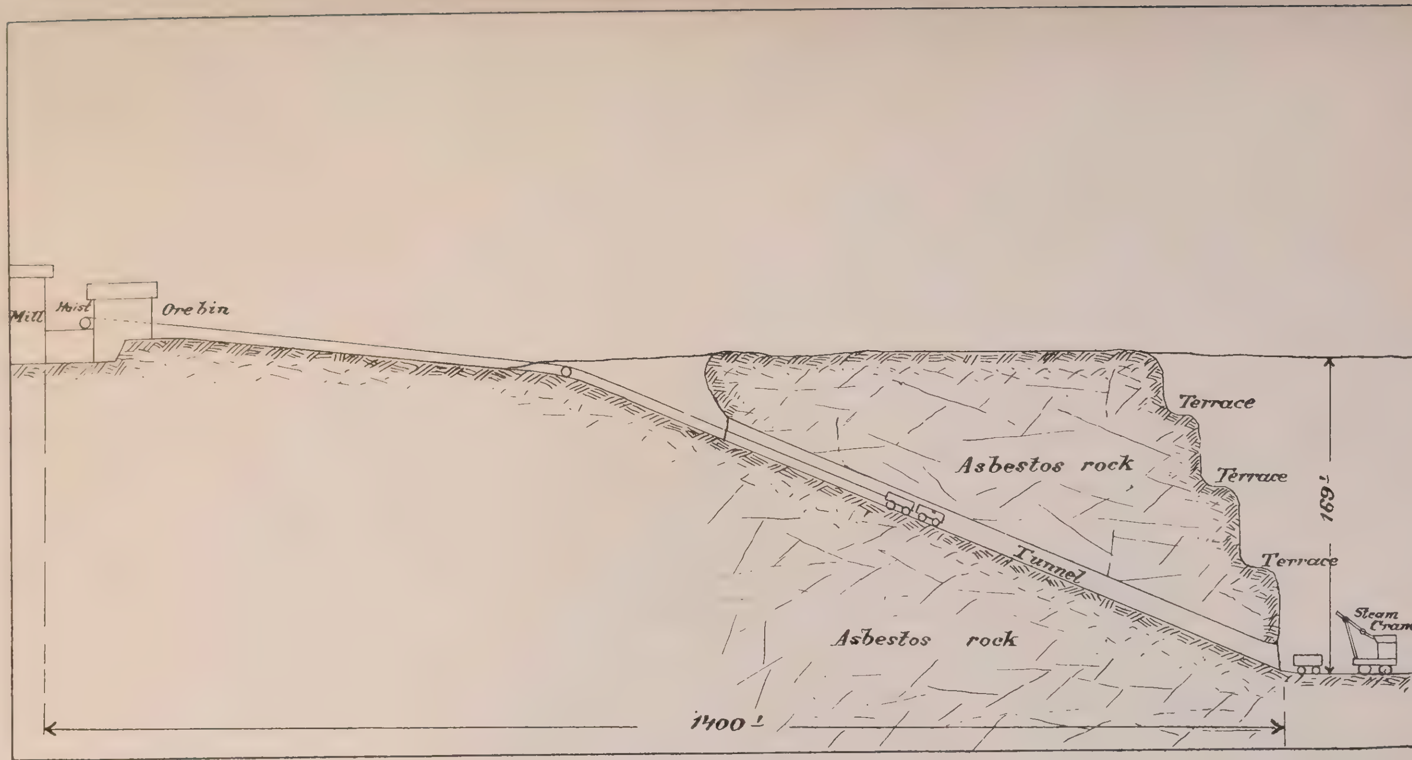


Fig. 26.—New mining method introduced in Bell mines.

pit, measuring over 1,000 feet in length, twelve cableways are being operated, and this necessitates twelve different hoisting units: each consisting of cableway hoist, cable tower, two or three heavy cables, and other accessories. Moreover, the operating expenses; the permanent watch necessary to keep these units in good order to prevent any accident; the time lost by the men in the quarry—as is generally the case—in watching the arrival or departure of the hoisting skips; are all factors which, when considered in the proper light, tend to offset, to some extent, the apparent advantages that at first sight appear.

These negative facts are now recognized by engineers, hence efforts have already been made to do away, to a very large extent, with the cableways in cases where larger quantities of rock are to be handled, and to substitute a tramway service instead—where the location of the quarry permits of such a course. The 'Bell' people, at Thetford, are the first to be credited with this innovation. When the present proprietors—Messrs. Keasbey and Mattison—took over the property several years ago, their manager, Mr. Geo. Smith, made a proposal to connect their great quarry with the mill: which was located at a distance of 1,100 feet, by rail through a tunnel, allowing at the same time a thorough exploration of a long stretch of virgin serpentine. This plan was at once accepted and executed, with the result that to-day all the rock, instead of being hoisted by cable derricks, is hauled in large 5 ton cars over a tramway through a tunnel to the mill. The advantages of this hoisting system are manifest, and need no further comment. There are a number of quarries in the district, the location of which permits the introduction of a similar tramway service; and although the initial expenditure of making a tunnel or open-cut in connexion with the tramway may be high, yet the operating expenses are so low, compared with that of ordinary cable derricks, that the money invested may be considered well spent.

Compressed Air.

In some of the larger mines the motive power for actuating rock drills and hoists is compressed air: generally supplied by straight-line air compressors.

In order to secure uniformity of pressure, and to get rid of the water, and impurities, the air is led from the compressor into a receiver, which is generally supplied with a safety valve, and pressure gauge, also a cock for letting off the water which gradually collects.

Where the distance of the pit from the air compressor is long—over 500 feet, a second receiver is installed about half way, for the purpose above indicated. The capacity of an air compressor is generally estimated by the number of rock drills it can supply. There are 3, 7, 14, and 20 drill, air compressors, all of which are employed in the asbestos region. The pressure usually produced for air drills is 80 pounds.

The straight-line air compressors which are extensively used in the district, have the great disadvantage of consuming too much steam. They are now being superseded by the duplex, compound steam-air compressors, manufactured by the Rand Drill Company, which are constructed on more economical lines.

Ore pockets and pan conveyor installed at the quarries of the Jacobs Asbestos Mining Co., Thetford, Que.

Drainage.

The serpentine rock, as a rule, does not carry much water. Most of the water comes from the surface, and is collected at the deepest point, in a sump. A duplex pump of the smaller size is generally stationed at some point of the quarry; is well protected against shots, and suffices to keep the water in the sump at bay by being operated only a few hours a day.

CHAPTER IV.

THE DRESSING OF ASBESTOS FOR THE MARKET.

Under the term dressing is generally understood the process by which the miner converts his mineral into a saleable article, or by which he extracts a marketable product from it. This process in the case of asbestos is divided into, (1) hand dressing; and (2) mechanical dressing.

Hand Dressing.

Since mechanical dressing is practised in all the quarries, hand dressing is confined to the cobbing of No. I, and No. II grades only.

Some mines make only No. I crude, measuring over $\frac{3}{4}''$ in length; while in others, besides the above, a No. II grade is made measuring from $\frac{5}{16}''$ to $\frac{3}{4}''$ in length.

As already mentioned above, the separation of the useful from the useless material is made in the pits after blasting: the larger pieces of rock being broken up, and the fibre gathered into boxes and sent to the dressing sheds; while the so-called fines and stones containing small fibre are sent to the mill for mechanical treatment.

In some of the larger quarries the process of hand-cobbing—as a result of many years experience—is worked out to great perfection. The following is a description of the hand-cobbing process pursued for over fifteen years in one of the principal quarries.

There are two cobbing-sheds at this mine: one in which men only, and another in which girls only, are employed. The men's cobbing-shed receives all rock containing the longer fibre. Small one-hand sledge hammers weighing from six to seven pounds are used in breaking up the rock, the longer fibre being screened by a sieve with $\frac{3}{16}''$ holes, and sent to the girls' cobbing-shed; while the screenings, and the rock containing small fibre, are delivered to the mill.

In the girls' finishing-shed—which receives besides the products of the men's cobbing-shed also the loose pieces of fibre from the pits—the girls are seated at long tables, having underneath a series of compartments for the reception of the Nos. I and II fibre. The hammers used in breaking up the rock and freeing the fibre from the same, weigh from 3 to 4½ pounds, and the steel plates upon which this work is done are 10″ to 12″ square, and $\frac{3}{4}''$ thick.

In order to get rid of all adhering rock particles, the No. I fibre is cleaned by a sieve with $\frac{3}{16}''$ holes, and the No. II fibre by a sieve with $\frac{3}{8}''$ holes. All refuse from the cobbing table and screenings is sent to the mill for mechanical treatment. The crude fibre ready for the market is put up in bags holding 100 pounds.

The cost of cobbing the crude varies considerably, due to the character of the rock in which the asbestos is found, and according to the care exercised in

freeing the fibre from rock particles. While in some quarries the cost per ton may be only $10; in others it runs up as high as $25. No average cost can be specified, since the exigencies of the market determine to a large extent the state into which the different grades have to be worked.

It is not claimed that the process outlined above effects a complete separation of the fibre from the rock, for the crude still contains some 5 or even 10 per cent of rock; but it is the outcome of some fifteen years' experience, and has given better results as to extraction and cost than any other known method.

Most of the companies working on ground containing a limited quantity of crude, do very little hand-cobbing, and extract only No. I, the balance being subjected to mechanical treatment, which accomplishes the extraction of the fibre, with a saving of time and labour.

Mechanical Treatment.

HISTORY.

The first attempt to solve the difficult problem of extracting the mineral from the rock by means of machinery, made in 1889, was by the Scottish Canadian Asbestos Company; now owned by the Amalgamated Asbestos Corporation. This plant consisted of a 50 horse-power engine, Blake crusher, travelling picking tables, a set of Cornish rolls, revolving screens, elevators, shakers, and two large blowers. This mill was erected according to the plans of Mr. Earle C. Bacon, Engineer, New York. In 1890, Mr. R. T. Hopper—at that time managing director of the 'Anglo-Canadian Asbestos Company,' of Black Lake—experimented with the ore in a small mill: consisting of a 'Blake' crusher, rolls, shaking screens, and a fan, and succeeded in producing a fibre of marketable quality. In 1890 and 1891 the 'American Asbestos Company,' (Union mines)—now owned by the 'Black Lake Consolidated Asbestos Company'—began experiments with the ore. The main object of this Company was, to do away with the almost indistinguishable No. III grade. This, however, was difficult to realize, unless the fibre could be thoroughly loosened and freed from the rock. The method adopted was as follows: the rock first passed through a 'Blake' crusher, falling upon an inclined shaking frame which separated all the loose fibre and dust from the larger pieces of the asbestos rock; the fibre going directly to a cleaning and grading machine, while the asbestos rock dropped on a revolving picking table. Here the barren rock was separated from the asbestos by hand. The latter was then dried in drying kilns, and sent to the fine roll crushers.

The crushed material went over cleaning and grading machines which consisted of a set of inclined sieves in rapid shaking motion, in connexion with blowers, fans, etc., the remaining unbroken stone and fibre going again through a set of still finer rolls.

The results obtained in this mill were not satisfactory, as the fibre so produced still contained a large amount of rock particles and dust.

King Bros., at Thetford, were the next to introduce machinery for the purpose of extracting small fibre from large pieces of rock in the dumps; which in

the beginning of the industry did not warrant the expenditure for block-holing and further handling.

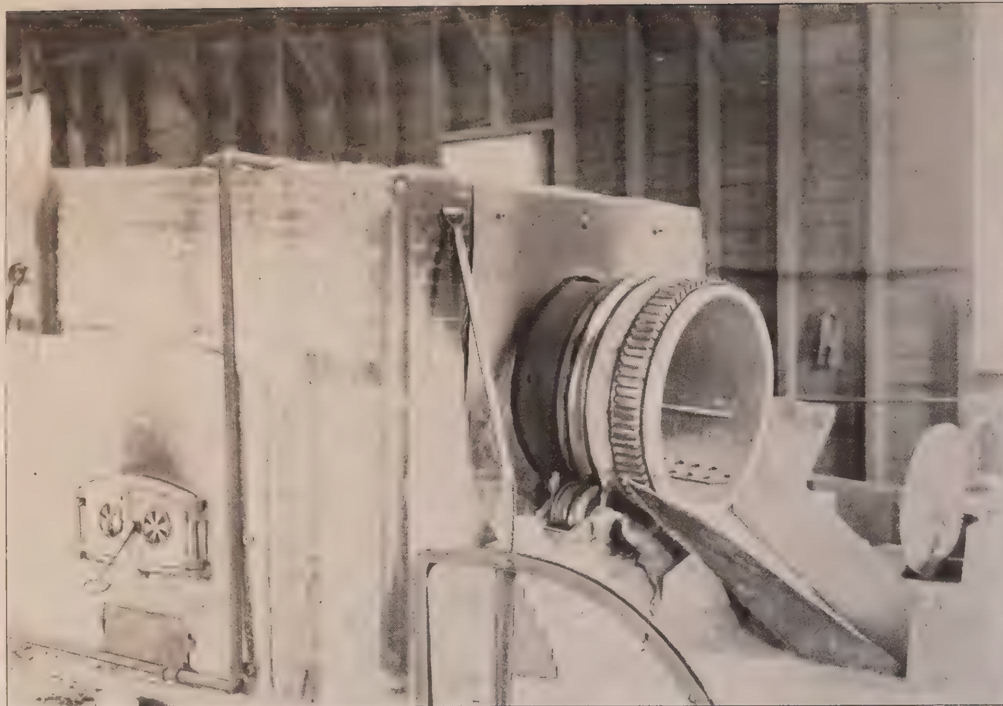
The plant consisted of a 'Blake' crusher, from which the material was conveyed to a set of Cornish rolls; a revolving screen then cleaned the fibre from dust. But this object was not fully accomplished owing to the failure of the rolls to crush the rock sufficiently. An additional blowing and screening apparatus was installed, which gave better satisfaction.

In 1893, the writer treated about ten carloads of asbestos rock, containing small fibre, received from the 'Templeton Asbestos Mining Company;' which was operating at that time the asbestos mines in Perkins Mills to the north of Ottawa. The mill used was located at Buckingham, and had been previously employed in the grinding and screening of phosphate rock. It consisted of a system of Blake crushers, Cornish rolls, a pulverizer, and screens, and after many changes—especially in the screening devices—the method worked entirely satisfactorily in liberating the ore from the rock; but a complete extraction of the fibre was not effected, owing to the lack of the necessary suction apparatus. When the latter was about to be installed, the mines shut down, and the experiments were consequently discontinued.

All the experiments carried on in the above mills conclusively demonstrated the great difficulty in freeing the fibre entirely from the dust and adhering rock particles. Owing, therefore, to the imperfect quality of the fibre so produced; the unwillingness of the manufacturer to buy prepared fibre at that time; and also owing to the trouble with the customs authorities of the foreign countries, who considered the fibred asbestos as a manufactured article, hence levied a duty thereon of 25 per cent ad valorem, the mechanical preparation appeared to come to a standstill.

In 1892, 1893, and 1894, several large shipments of prepared asbestos were made, and although the quality was not up to the expectations of the manufacturers, nevertheless, some of the latter realized the immense importance of the new innovation, having for its object the saving of the freight charges by the elimination of the rock in the different qualities of crude, which, in some cases, amounted to from about 15 to 20 per cent of the total weight. On the other hand, it was manifestly of the utmost importance for the mine owners to succeed in mechanical separation; since the large dumps resulting from the earlier operations contained a very large amount of short fibre, and did not warrant the comparatively large expenditure involved in extracting by hand-cobbing; and the saving of which would represent a valuable asset when the mechanical process of separation of the fibre became a success.

The Bell Asbestos Company, under the management of Mr. George Smith, commenced to experiment with the mineral in 1893, with the result that, a mill was built in the following year, treating small quantities of asbestos rock with success. Other companies followed suit, and shipments of fiberized material commenced in earnest in 1895, and 1896. From the last-named year on, the process of extraction has been steadily improved. Mills of large capacity were built; the percentage of crude became insignificant compared with the large output of the



Rotary dryer.

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fiberized article, and to-day every mine of importance is equipped with a complete milling and fiberizing plant.

Owing to the success of the mechanical treatment of the ore in extracting all the fibre from the rock, the life of an asbestos quarry, compared with that of some ten or fifteen years ago, is much prolonged; its operation is attended with fewer difficulties, and companies working on poorer ground, who had been obliged to shut down, were enabled to resume operations.

Apparatus Used in the Separation of Asbestos.

Before entering into a description of the different milling plants, and methods in use, it is necessary, in order to fully understand the working principles of the same, to describe the different classes of apparatus which, according to experience, have given the best results in mechanical separation.

DRYING OF THE MILL ROCK.

The mill rock and fines coming from the pits and cobbing sheds contain a great deal of moisture, and before this material can be subjected to further treatment, it has to be thoroughly dried. Various methods of drying the mill rock are applied:—

(1) Exposure to the air.

(2) Steam pipes.

(3) Rotary dryers.

(1) *Drying by Exposure to the Air.*—The material is spread over a large wooden platform in a layer 2″ or 3″ thick, as at the Johnson mine in Thetford. If the weather is favourable a sufficient amount of moisture evaporates naturally to render the mineral fit for treatment by the different processes of crushing and blowing; but a wet season interferes with the work, while drying by this process during the winter is impossible. This method is unstable and unreliable, and, for this reason, its application is very limited.

(2) *Drying by Steam Pipes.*—A number of 1½″, or 2″ steam pipes are arranged parallel to each other, close together on the floor of a shed, and joined at the ends to form a continuous length: one end terminating in a pipe of larger dimensions, connected with the exhaust of some steam engine; the other end leading into the open air. A track runs through the middle of the shed, allowing the fines to be unloaded at any point desired. All dried material is shoveled into an elevator placed at a convenient point in the centre of the shed, which delivers the same through a chute to the crusher of the mill. The advantages of this simple method may be summarized as follows:—

(1) No power is required.

(2) No extra fuel for drying.

(3) There are hardly any repairs.

(4) Danger from fire is eliminated.

(3) *Rotary Dryer.*—The rotary dryer, as illustrated in Plate XXXIX, consists of a long cylinder made of strong boiler plate, resting, and turning on its

ends on friction rollers. In order to allow the shell to expand, and at the same time to prevent it from sliding, these friction rollers are flat at the upper end and grooved at the lower end of the cylinder. The length of the shell is from 30 to 40 feet; the diameter from 2′–6″ to 4 feet, and its inclination 7°. The whole is bricked in, leaving only the ends of the cylinder with the friction rollers outside. The space between the arch and the cylinder is 6″.

The drying is assisted by longitudinal blades, which lift the material, and allow the same to fall through a current of hot air which circulates through the cylinder. The fire is either placed directly under the shell or, in an extra brick case, at the side, on the lower end of the cylinder, allowing the heated air to play round the shell and escape through a chimney placed at the other end of the dryer.

Sometimes, fires are made at both ends, the chimney in this case being placed in the middle of the apparatus. The cylinder is made to revolve from 6 to 8 revolutions per minute. The ore, which is charged by hand or by automatic arrangement, travels along slowly, is stirred up by the inside blades, and, as a rule, discharges into the elevator to the ore bin. The capacity of this rotary dryer ranges from 50 to 75 tons per shift: according to size, and the content of moisture in the material. The cylinder is kept in motion either by an endless chain round the lower end, or by gearing transmission, as illustrated in the plate.

The main advantage of a rotary dryer over all other drying methods is, its continuous operation, and its adaptability for the handling of a large quantity of ore in a comparatively short time. This device has its faults, however, also: the principal one being the necessity of frequent repairs caused by the bulging and twisting of the boiler plates.

Where the charging is done automatically, one man is sufficient to attend to the whole apparatus, otherwise, two men are needed.

The 'Campbell' Dryer, Fig. 27.—The principle applied to the construction of this dryer is the same as that used in the one above described, the only difference being, that instead of one, five small tubes—each of 15″ diameter—are arranged in a parallel position around a main axis, the whole making from 6 to 7 revolutions per minute. The standard size is 4′–6″ diameter by 35 feet long. This dryer, on account of its great efficiency, is gradually replacing the one tube dryer. Its drying surface is 714 square feet; and compared with a one tube dryer, 4 feet diameter, of the same length, and having a drying surface of only 439 square feet, it does 1·62 times more work for the same amount of fuel consumed.

The Drying Problem.

The drying problem has occupied the attention of the companies ever since the first year mechanical separation was inaugurated. Many devices have been tried; but, as a matter of fact, in almost every instance, after the spending of much money, the companies returned to the old 'rotary,' which has now been improved upon by 'Campbell' of Sherbrooke. The principal defect in all these rotaries is, their great consumption of fuel. If exact figures were available, they would show that the cost of drying varies from 2 to 15 cents per ton. There is,

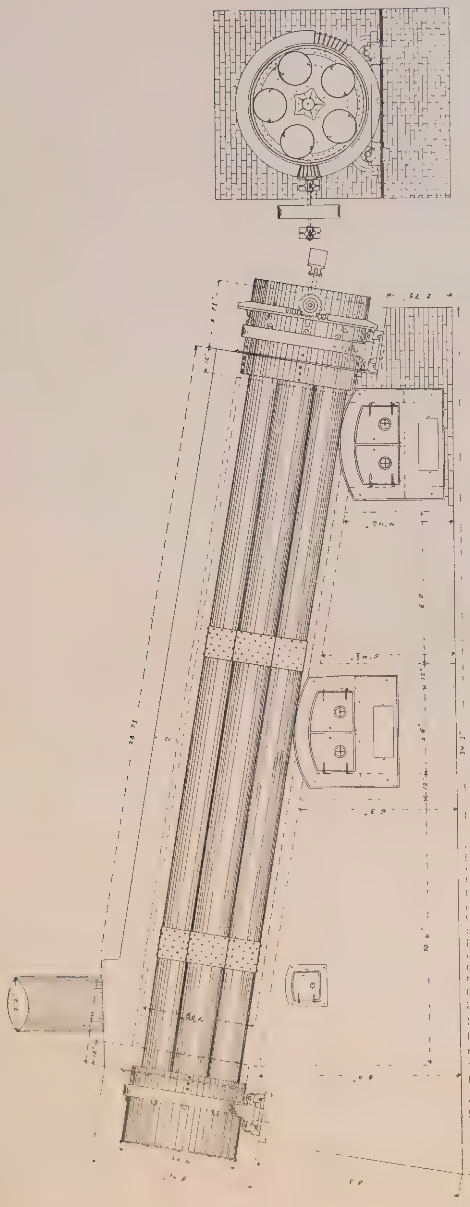


FIG. 27.—Campbell's patent rotary dryer.

in the opinion of the writer, no fault in the construction of the apparatus as a whole; and under proper care it is as satisfactory as may be expected under the circumstances; but the principle involved of burning fuel under free access of air, is manifestly faulty and uneconomical. There are three sources of losses:—

(1) Incomplete combustion.

(2) Heat escaping in exhaust gasses; and

(3) Heat carried away by dried rock.

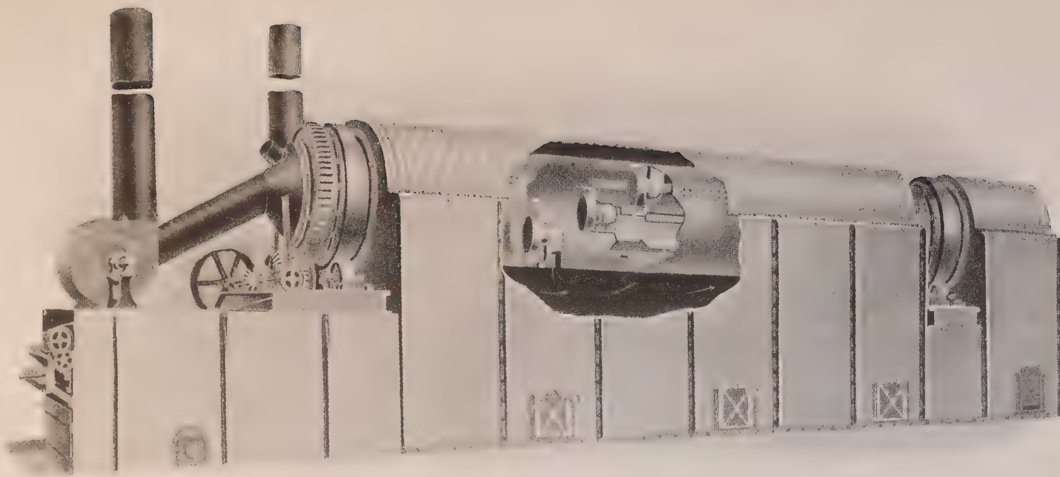
As a general rule, in an open fire such as we find under a rotary dryer, this access of air is not regulated according to conditions prevailing in the combustion chambers. In the majority of cases an entirely inadequate combustion of the fuel is the result. The shell becomes coated on its outer surface: first with a fine film of carbon; which is subsequently covered with another film as combustion progresses, and so on, until finally a thick mantle of soot separates the material to be dried from the fire. This thick coating is a non-conductor of heat, hence instead of communicating the heat to the shell and the material inside of the same, it absorbs a great deal of it with the consequent result that the material is not properly dried.

This loss of heat due to incomplete combustion is generally ignored; but it is, nevertheless, a considerable item. To prevent this loss of carbon, large combustion chambers must be supplied in order to produce a perfect mixture and chemical combination of the oxygen with the carbon monoxide.

But the largest loss of heat—amounting sometimes to 30 per cent and more —occurs in the exhaust gases; especially in dryers where natural draft is used to burn the fuel. Here, as in every steam boiler, the temperature of the exhaust gases is rarely below 400° F; sometimes it is over 600°, or even more. In order to overcome these losses an exhaust fan should be placed at the upper end of the dryer; so that the gases are drawn against the flow of the material to be dried; in this case the heat is in constant contact with the cold and wet material. Condensation of the steam takes place; but the loss is very small, since the heat liberated in the condensation is entirely consumed by the rock and aids to some extent in drying the latter in the process. If, on the other hand, the current of the gases is reversed, that is to say, that the draw of the gases is with the flow of the drying rock, experience shows that a temperature of at least 212° F must be had in the exhaust, so that no condensation may occur and no moisture deposited upon the rock to be dried.

The heat up to 212°, carried out with the dried rock, cannot be considered as loss, or should not be charged against the efficiency of the dryer; because that temperature is about the minimum required for the rapid drying of the material. All heat, however, above that temperature of 212°, is unnecessary and, therefore, should be considered as a loss.

Another serious defect in the operation of the 'rotary' used in the district is the insufficient draft inside the tube, or the slow replacement of the moist, by dry air. In very rainy days the mill material is saturated with water, and the latter when coming in contact with the hot shell of the dryer is evaporated, filling the tube, so to speak, with steam. As the natural draft is not strong enough to draw off the latter quickly, the material in the tube is constantly



Cummer dryer.

moved around in a steam bath, with the result that the drying of the material is greatly retarded thereby, necessitating a comparatively large amount of extra fuel per ton. If care were taken to draw off the moisture immediately it is produced in the tube, the material would dry much quicker, and the cost per ton dried, would, as a consequence, be far less than it is with the present arrangement in the mills.

One dryer which seems to a certain extent to overcome the two principal difficulties mentioned, and which has been used successfully in drying other material, such as peat, gypsum, lignite, and all kinds of chemicals, is the 'Cummer dryer,' illustrated in Plate XL.

This apparatus is a 'direct heat' dryer, and does away with the loss of heat radiation through the incomplete combustion of the fuel gases. Briefly, this dryer consists of a steel plate cylinder revolving on steel rolls or trunnions. An exhaust fan conveniently placed on top of the furnace draws the gases through apertures, covered with a cast-iron hood or cap, and made into the shell of the cylinder into the latter, as indicated in the plate. The material on entering the cylinder commences to dry and in travelling towards the end loses more and more of its moisture. A sufficient number of hoods are placed alongside the shell to allow about three-fourths of the heated air and gases to enter the cylinder: the balance entering the latter through the rear or lower end. The result is, that there is, here, hardly any circulation, and for this reason little, or no dust is blown out in the discharge of the material. The temperature of the heated air and gases is gradually lowered by the cold air coming through the registers in the side of the brick walls. The air, gases, and moisture, thus pass in opposite directions over the drying material by way of the exhaust fan into the open air. The capacity of a 'Cummer dryer' of a medium size is 400 tons in 24 hours; and it is guaranteed by the manufacturers that only one ton of combustible is used for every 100 tons of rock dried. Several of the new 'Cummer' dryers are installed in new mills, and the results are being watched with a great deal of interest.

Rock Breakers.

The rock breakers employed in the district are of two classes:—

(1) The jaw breakers, which are intermittent machines.

(2) The rotary and spindle, or gyrating breakers, which are continuous machines.

Jaw Breakers.—The first crusher through which the rock has to pass is invariably a jaw crusher of large size. This is a machine for reducing rock preparatory to fine crushing by rolls. It is durable and simple to operate. The rock is crushed between jaws: one stationary; the other swinging, and driven by a powerful toggle movement.

The adjustment of the jaws and the size of the rock leaving the crusher is determined by the character of the apparatus used in subsequent treatment. One rock crusher alone may be used to prepare the rock for the rolls, gyratory or rotary crushers; but for a larger capacity it is preferable to use two sizes with a screen between; since the second crusher relieves the subsequent apparatus of a great deal of work.

Inasmuch as the large size and irregularity of the feed-rock generally, does not admit of automatic feeding, the jaw breakers are fed by hand and shovel; in many cases by a chute, sloping from the bottom of a bin, the attendant pulling forward the ore in the chute with a rake or pick.

The jaw breakers may be divided into two different types, according to the movement of the jaws:—

(1) Those which are pivoted above: giving the lower part of the jaw the greatest movement.

(2) Those which are pivoted below: giving the upper part of the jaw the greatest movement.

To the former class belong the 'Blake' crushers; to the latter the 'Dodge' crushers.

The movement of the lower part of the jaw is greater in the Blake crusher, and the result is, that a product of various sizes must drop from the machine; whereas in the Dodge crusher the movement is greater at the top of the jaw, the lower part remaining nearly stationary, hence the product leaving the machine is of nearly uniform size—determined by the distance the jaws are set apart. This explains the higher capacity of the Blake; while the Dodge crusher delivers more fines, and a more uniform product.

The jaw crushers are manufactured in many sizes: those most in use in the district have openings varying from 16″ × 10″ to 30″ × 15″. The capacity for each size varies according to the product desired.

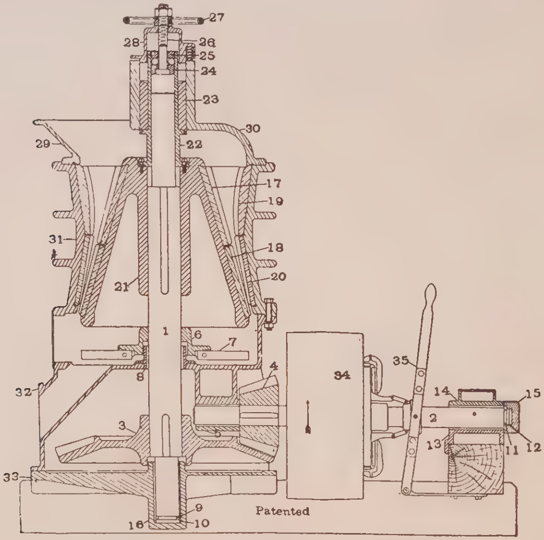
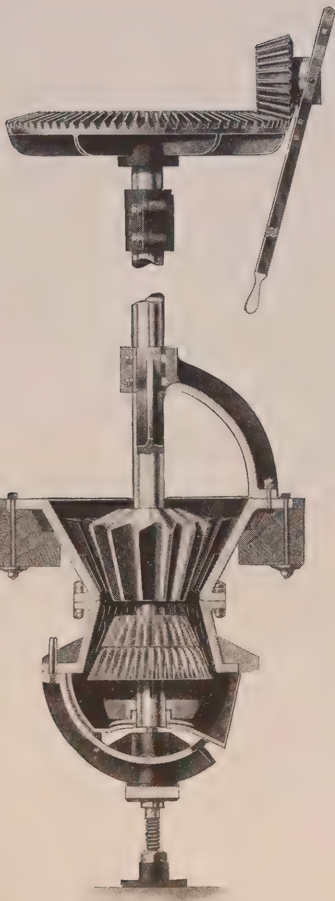


FIG. 28.—Sturtevant Rotary Crusher.

Rotary Crusher.—The rotary crusher has recently been introduced into a number of new mills, and is usually fed with the product from the jaw breakers. A section of the machine is shown in Fig. 28.



Butterworth and Low rotary crusher.

Description.—The vertical shaft (1) carrying the driving gear (3) runs in a large oil pot bearing (10) thoroughly protected from dust. The crushing cone (21) is supported from the top by large ball bearings which promote easy running and durability. This cone is raised or lowered by a screw (26) from the top and the range of adjustment for wear or to size output is large.

The scrapers (17, 18, 19, and 20), require no change, except replacement for wear, and are conveniently reached without dismantling the machine. Having no fly-wheel, this crusher is not subjected to fly-wheel shocks in case of sudden stoppage. The machine is made in three sizes, of which size No. 2 with a hopper opening of $20'' \times 30''$ is the one mostly in use. The capacity of this size is from 8 to 12 tons per hour; the horse-power required is from 15 to 20, and the revolutions per minute 250.

The rotary crusher manufactured by Butterworth and Low, Grand Rapids, Mich., is a heavy machine of the coffee mill type, and consists of two parts (Plate XLI): an upper part, A, for coarse crushing, and a lower part, B, for fine crushing. All the crushing surfaces are of hard chilled iron. This apparatus will receive rock up to 6″ to 7″ diameter, and reduce it—if desired—to an average size of kernels of corn. Its capacity is from 7 to 13 tons an hour, and the horse-power required from 8 to 11.

Several improvements have been made since the first edition of this monograph was written; the principal one being the possibility of lowering the bottom of the machine together with the shaft, discharge pan, and lower and upper burrs, for the purpose of cleaning the mill. Millmen claim that this apparatus, on account of its compact and heavy construction—its weight being 6,000 pounds —and of the drop base, allowing quick access for cleaning out or replacements, gives little trouble, is very efficient, and is specially adapted for grinding asbestos rock.

The Spindle or Gyrating Breakers.—Among these are several types; but the most common form used in the district is the Gates type (Plate XLII). It consists of a bottom plate: (1) a bottom shell, (2) including a chute (32) for the crushed ore; a top shell; (3) a two-armed spider, (6) furnishing the bearing for spindle (25). This spindle can be raised or lowered by a screw (24) in the bottom plate. The lower end of this spindle is a journal and finds a bearing in the eccentric hub, firmly attached to bevel gear (9). While the interior surface of the hub is an eccentric bearing for the spindle journal, the exterior surface is a journal, which is concentric with the gear and finds its bearing in the bottom plate. When the bevel wheel revolves, the spindle is free to gyrate or rotate in the eccentric (8). Practically it rotates until ore is fed between the crushing surface (18 and 19), it then gyrates.

The gyrating motion causes the head (18) to approach and recede from the concaves (19), and owing to the fact that the spindle acts as a lever with one end in the spider, it will cause a greater movement at the lower end than at its upper end, and produces a crushing action by pressure upon the lumps of rock.

The angle of gyration varies a little, requiring a small amount of play in

the upper and lower journals. The total vertical movement of the spindle is $3\frac{1}{2}''$ in the larger breakers, and $2''$ in the smaller ones.

The larger lumps as broken, fall a short distance to a fresh bearing, to be broken again by the next act of compression; and this is repeated until they are broken fine enough to pass between the concaves and the head at the narrowest point. The ore then passes out over the chute.

The Gates crusher is made in five sizes, the smallest one having a receiving opening of $8'' \times 30''$; the largest one $21'' \times 76''$. The two sizes chiefly in use in the district have openings of $8'' \times 30''$ and $10'' \times 38''$, with respective capacities of 15 to 40 tons of rock per hour, according to the product desired. The number of revolutions of the driving pulleys is from 350 to 400 per minute, and the power required from 15 to 25 horse-power.

Final Crushing.

The machines for final crushing receive the ore from the rock breakers and rotary gyrating crushers, and are suitable for separating the fibre from the waste preparatory to the separation by exhaust fans. They act on the principle of crushing by direct pressure, as in the rolls, or by centrifugal force, as in the fiberizers and cyclones.

ROLLS.

The chief parts which enter into the construction of a pair of rolls, are two shafts upon which are usually mounted permanent cores of soft cast-iron, carrying shells of rolled steel or chilled iron, which constitute the crushing surfaces. One shaft revolves in fixed; the other in movable boxes.

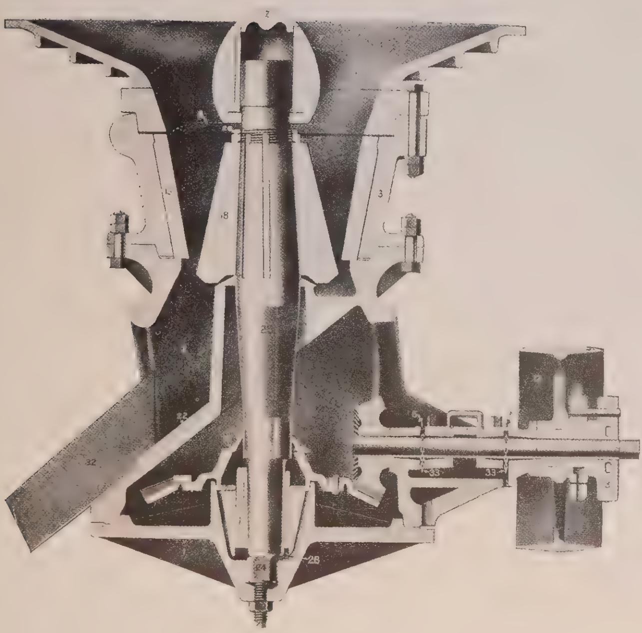
In some rolls the shells are made of manganese steel, which has an extraordinary hardness and toughness, and lasts much longer than those made of ordinary steel or chilled iron.

The shaft in the movable boxes is held towards the fixed boxes by powerful springs: the degree of approach being regulated generally by compression bolts. The space between the rolls varies from practically nothing up to $\frac{3}{4}''$. The relation between the diameter of the ore fed and the space between the rolls, that is to say, the amount of reduction, is of great importance if the rolls are to do their work. In some mills the ore is fed in nut size; in others, in much smaller lumps, and the spaces between the rolls are adjusted accordingly.

Some rolls receive the ore from the breakers; others from a rotary or gyrating crusher, and others again from a first pair of rolls. They are, however, rarely fed with lumps larger than $1\frac{3}{4}''$ in diameter; generally with an admixture of fine grains. In taking the rock for the rolls from a breaker or other apparatus, the supply of ore is regulated and the output limited; but it often happens that a sudden rush of ore will choke the rolls, hence, unless they are supplied with an extraordinary amount of power and strength—which is generally not the case—they will break, especially those which are driven by gears and pulleys.

In some mills, to avoid these troubles indicated, feeders are used, kept constantly full of material, which is fed to the rolls by an oscillating gate. Small

Plate XLII.



Gates crusher, manufactured by the Allis-Chalmers Co., Chicago, Ill.

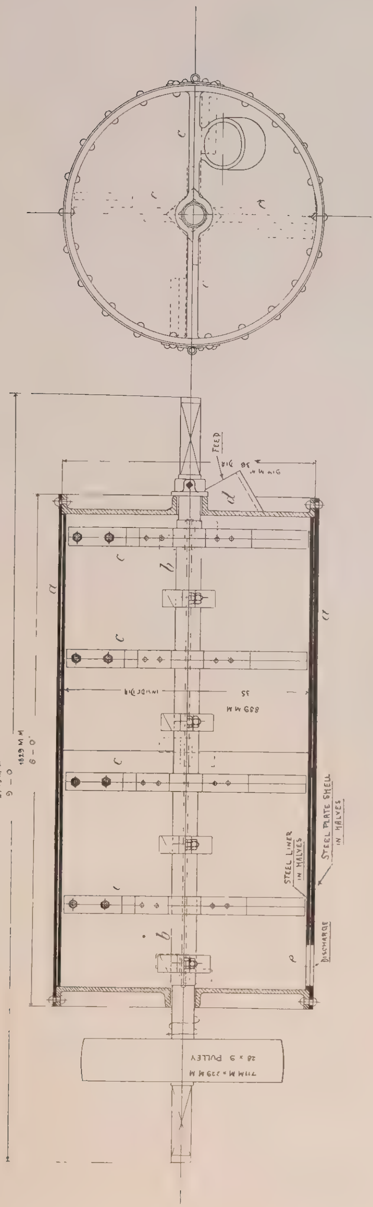


FIG. 29.—Fiberizer manufactured by the Jenckes Machine Co., Sherbrooke, Que.

scrapers are also used in several cases to remove the adhering fines from the face of the rolls at the lowest point in their revolution.

There are two designs for the driving mechanism of rolls: one is the gearing motion, the other by a belt drive. In the gearing mechanism one roll is connected on one side by finger gears, and on the other by pinions. In the case of the belt drive, each roll is driven by a large pulley. These pulleys are driven either by one open and one crossed belt from the same shaft, or by two open belts from separate shafts running in opposite directions. When a crossed belt is used, it always drives the adjustable roll.

Some mill men prefer corrugated rolls. It is claimed that the corrugated surfaces produce a sort of grinding action, thus crushing the rock finer and liberating more fibre. However, opinion amongst mill men differs on this point. In some mills corrugated rolls have been installed and worked for some time, but they have been subsequently replaced, for some reason or another, by rolls with flat surfaces.

Crushing rolls are made in five sizes: having from 12″ × 10″ to 36″ × 18″ rolls. The minimum and maximum capacities are 1 and 8 tons, respectively, per hour: according to the desired product; from 5 to 20 horse-power being required for the purpose. All rolls make from 125 to 150 revolutions per minute.

FIBERIZERS.

The machinery so far described has for its main object the liberation of the asbestos fibre from the rock by repeated crushing; but in order to make the mineral more amenable to the exhaust and pneumatic process—which will be dealt with presently—it is necessary that the coarse fibre or stone asbestos, which for the most part leaves all the previous apparatus in the form of small lumps, be divided and split into fine fibre of feather-like weight and appearance.

This operation, and the work of crushing still finer the small lumps coming from the crushing apparatus, is performed in so-called fiberizers, of which there are two kinds in use, the cylindrical beaters and the cyclones.

'Jenckes' Fiberizer or Beater, Fig. 29.—This consists of a cylindrical shell (*d*) made of steel plate with cast-iron heads and steel plate liners, composed of halves, and hinged together so as to facilitate opening for cleaning and repairs; and a shaft (*b*) with eight arms (*c*). The shaft is turned round at the ends in the pulley and bearings; the arms are made of heavy steel bars, carrying at the outer ends chilled iron beaters, the faces of which are made on an angle so as to drive the material from the feed (*d*) to the discharge end (*e*). This machine runs about 300 revolutions per minute.

CYCLONES.

The cyclone machine is now used in almost every asbestos mill, and forms one of the integral parts of asbestos separation. When this apparatus was first introduced, its working principle was not well understood and appreciated. It had also faults in construction; but experience soon brought forward essential improvements, with the result that, the asbestos industry has, to-day, a fiberizer,

without which the efficiency of the mills would be considerably reduced. It is true that the cyclone by its violent action tears up a part of the fibre; but as long as there is no other apparatus which will do the work better, the cyclone will stay, and be one of the chief appliances in asbestos separation.

This apparatus is simple in construction. It consists of two beaters, A, (Fig. 30) of the screw propeller type, driven at a speed of 2,000 to 2,500 revolu-

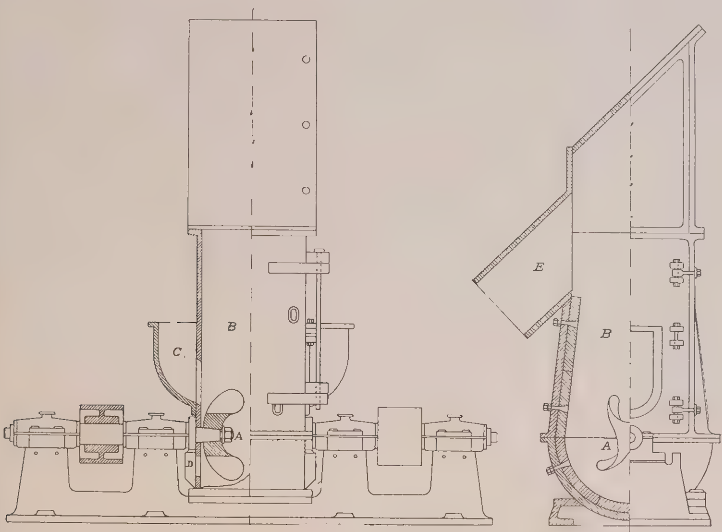


FIG. 30.—Laurie Cyclone Fiberizer.

tions per minute, in opposite directions, in a cast-iron chamber or case, B. The material is regularly fed through the feed holes, C, and the whirlwind created by the beater hurls the particles against each other with such violence that they are almost instantly reduced to fine grains, or even to impalpable powder.

A fan connected with the apparatus causes a suction in the interior, air being supplied through the little vent holes, D, and all material reduced to about peanut size and smaller, is thrown out through the discharge pipe E. As a rule, the discharged material falls on a shaking screen, and the latter is placed together with the discharge pipe in an air-tight box, connected with an exhaust fan.

Although the blades are generally made of chilled iron, they wear out very rapidly, and have to be replaced every ten or fourteen days—according to usage and quality.

The capacity of a cyclone depends upon the conditions of the rock; the average size of rock charged, and the product desired. In mills where the rock is hard and tough, only from 25 to 30 tons can be put through in a 10 hour shift. In others, from 40 to 50, and even 60 tons can be treated. As a rule, the size of the rock charged is not larger than a walnut; while the bulk of the discharge is about peanut size.

Many attempts have been made to improve the cyclone; they are all directed towards preserving the natural length of the fibre by eliminating or reducing the tearing effect which the rapid revolving motion of the blades exercises upon the mill material. At the time of this writing two different types of cyclones are being tried: one the invention of Mr. Pharo at the Beaver mines and the other one designed by Mr. Torrey of Black Lake.

The Pharo cyclone is essentially a cyclone of the old style with these alterations: the hood above the discharge end E (Fig. 31) is cut off immediately above the latter, and the crushing blades or beaters rotate in the same direction. Several of these cyclones have been in constant use for over four months at the

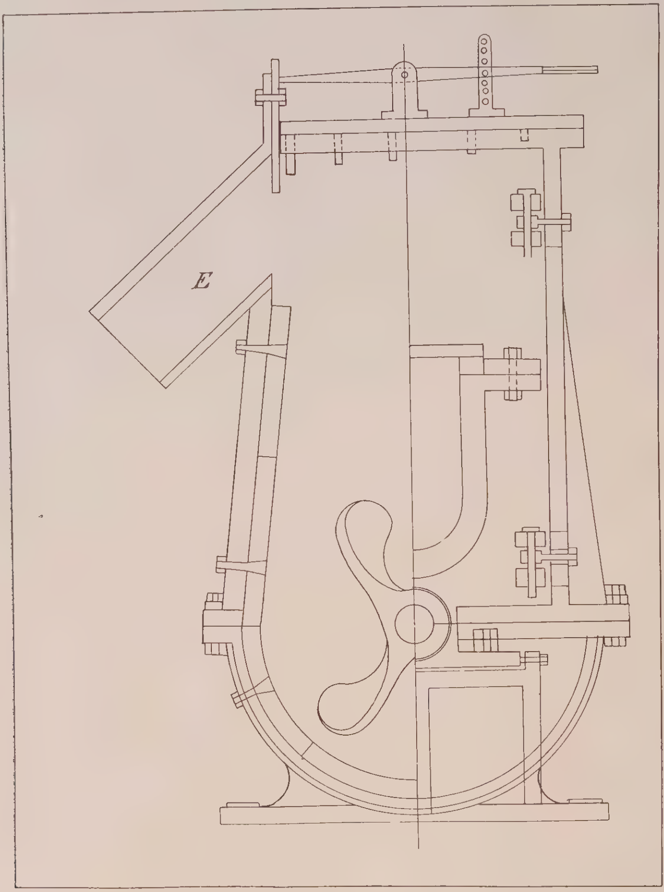


Fig. 31.—Section through new Pharo Cyclone.

Beaver mills and have given good satisfaction. They possess several advantages over the old type: they require less power, only 35 to 40 horse-power,

against the old one of 70 and 75. The average life of the beaters in the old cyclone was 80 to 100 hours, in the new cyclone it is from 500 to 600 hours. These cyclones have the advantage also of convenient regulation, because a gate on the discharge end allows the material which is thrown against chilled cast-iron bars fastened to the cover to be crushed to the desired size.

PULVERIZERS.

In some mills the tailings are ground to a very fine powder used for plastering, in so-called Emery mills. These mills, as illustrated in Fig. 32, are made either with horizontal or with vertical stones. In the horizontal emery mill the

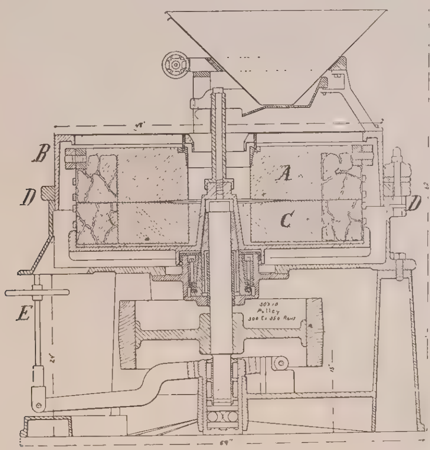


FIG. 32.—42″ Sturtevant horizontal, direct running Emery Mill.

bedstone A is bolted strongly to the top case B, and is lowered with it directly upon the runner stone C, with which it is then in perfect adjustment. The clamp ring D is then tightened, and grasps the bedstone case, firmly holding it and its stone immovably in position. The runner can now be lowered away from the bedstone by the hand wheel E to such a distance as gives the fineness of grinding required. This simple and accurate adjustment of the mill stones is of special value, since it ensures good results with ordinary help. The stone makes from 300 to 350 revolutions per minute; the capacity of a 42″ mill is from 1 to 3 tons per hour, necessitating 18 horse-power approximately.

In the vertical Emery mill the adjustment of the stones for coarse or fine grinding is accomplished by turning a hand wheel at the end of the shaft. A 30″ mill having a capacity of from 2 to 4 tons per hour, according to fineness desired, requires from 18 to 20 horse-power to run it, and makes about 650 revolutions per minute.

FANS.

All fiberized asbestos is taken up from the screens by suction fans, and is blown into collectors or settling chambers.

For this purpose the suction pipe A, (Fig. 33) of fan B, ends in a flattened attachment which tapers in one direction from a diameter of 12″ of the pipe A to 6″, and widens in a direction perpendicular to the former, to the width of the

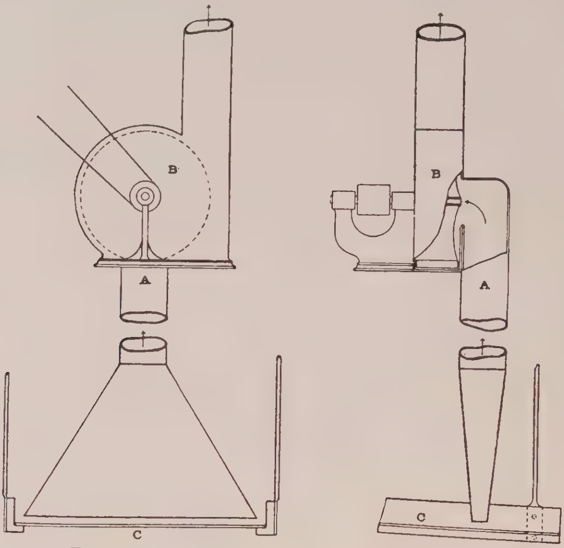


FIG. 33.—Fan for taking up fibre from shaking screen.

shaking screen C. The fans are made of heavy galvanized iron, are 30, 35, and 40″ diameter, and make from 1,800 to 2,200 revolutions per minute. In all the mills there is so much floating dust that extra fans are needed to remove the same.

ACCESSORIES FOR MILLS.

Screens.—There are two kinds of screens in use: flat and cylindrical. Both are made of wire or perforated galvanized iron. The oscillating movement of the shaking screens is generally caused by eccentrics; the wooden frames being supported from suspending rods. The screens are used in all sizes, from 3 × 6, 6 × 12, and 10 × 20 feet. The number of pulsations varies in the mills from 200 up to 300 per minute. Apart from the sizing of the rock and the elimination of the sand, the principal purpose of the shakers is the complete separation of the fiberized asbestos from the rock after it has passed the crushing machines and beaters. The oscillating movement causes the fiberized material in its downward course to come on top of the rock, thus allowing the fans to suck up the fibre and place the same in collectors or depositing chambers.

The revolving screens are nearly everywhere used for the grading of the fibre only. They have arms moving in opposite directions, mounted on a double shaft, for the purpose of loosening the fibre in order to effect a better separation through different meshes, of which the wire cloth is composed.

Conveyers.—The conveyers used in the mills are all of the endless belt or chain type, which move the product to be conveyed, forward. The belt conveyer consists of an endless belt, generally a rubber belt, running on two pulleys or drums, with intermediate supporting rollers. They are extensively used now, for the transport of the dried and crushed ore to the mill proper; for the transport of the tailings from the mills, and as continuous picking tables. Bucket elevators, consisting of a series of steel buckets hung on trunnions between two parallel link belts, are mostly used between dryer and crushers and fiberizing machines, to deliver the product from one apparatus to the other.

Collectors and Settling Chambers.—The asbestos fibre is blown by fans into collectors or settling chambers. The construction of a collector is shown in Fig. 34. The fibre enters the upper part of the collector through A, the dust escaping through an inverted chimney B, and the fibre falling through discharge tube C onto a conveyer or into a grading revolving screen. The collectors are

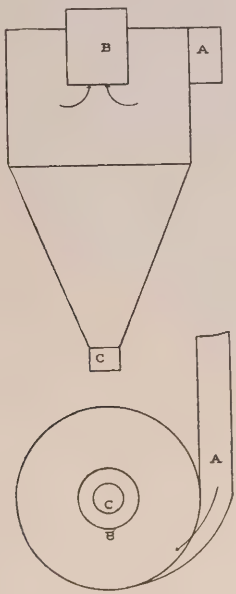


FIG. 34.—Collector.

generally made of galvanized iron, in sizes ranging from 3′–6″ to 6 feet diameter. As a rule, every collector receives the product of one screen, the larger collectors sometimes from two screens. The settling chamber consists of a room with a longitudinal hopper, at the bottom of which is installed a conveyer (Fig. 35). The fibre enters through the pipes, A, on the sides of the chamber, and falls onto the conveyer, B; the dust escaping through the vent holes, C.

All collectors and settling chambers are generally placed near the roof. In some mills the dust emanating from the collectors—on account of its content of

very fine short fibre—is collected in large receptacles placed under the roof of the mill building, and is used in connexion with the manufacture of finishing plaster.

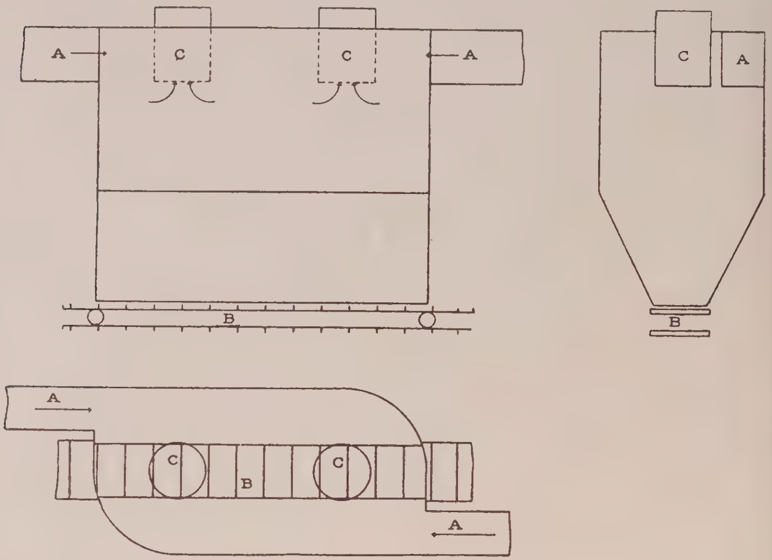


FIG. 35.—Collecting and settling chamber.

Ore Bins.—The varying production of ore in the mines calls for receiving bins large enough to serve for storage when the mine is producing more than the mill can treat, and thus provide ore for the mill when none is received. At most of the quarries, mining is done only for one shift; while milling is going on for two shifts. A common rule for the size of bins is that they shall hold at least the output of the mining operations for two shifts; although they are often of much larger capacity. Intermediate bins are used in some mills to act as reservoirs, so that a temporary stoppage of one part of the mill will not necessitate the stoppage of the parts preceding and following.

SUMMARY OF PRINCIPLES IN THE SEPARATION OF ASBESTOS.

Having described individually the various kinds of apparatus which find application in the asbestos mills, there now remains the consideration of the mill as a whole: including the various combinations of principles; the different arrangement of apparatus; and general items, such as power, costs, etc., and mill testing.

Although the method applied in asbestos separation is practically the same in every mill, no two mills are built alike. The serpentine in the different localities varies in hardness and toughness; one quarry extracts Nos. I and II grade by hand; another only No. I grade: while others have abolished hand

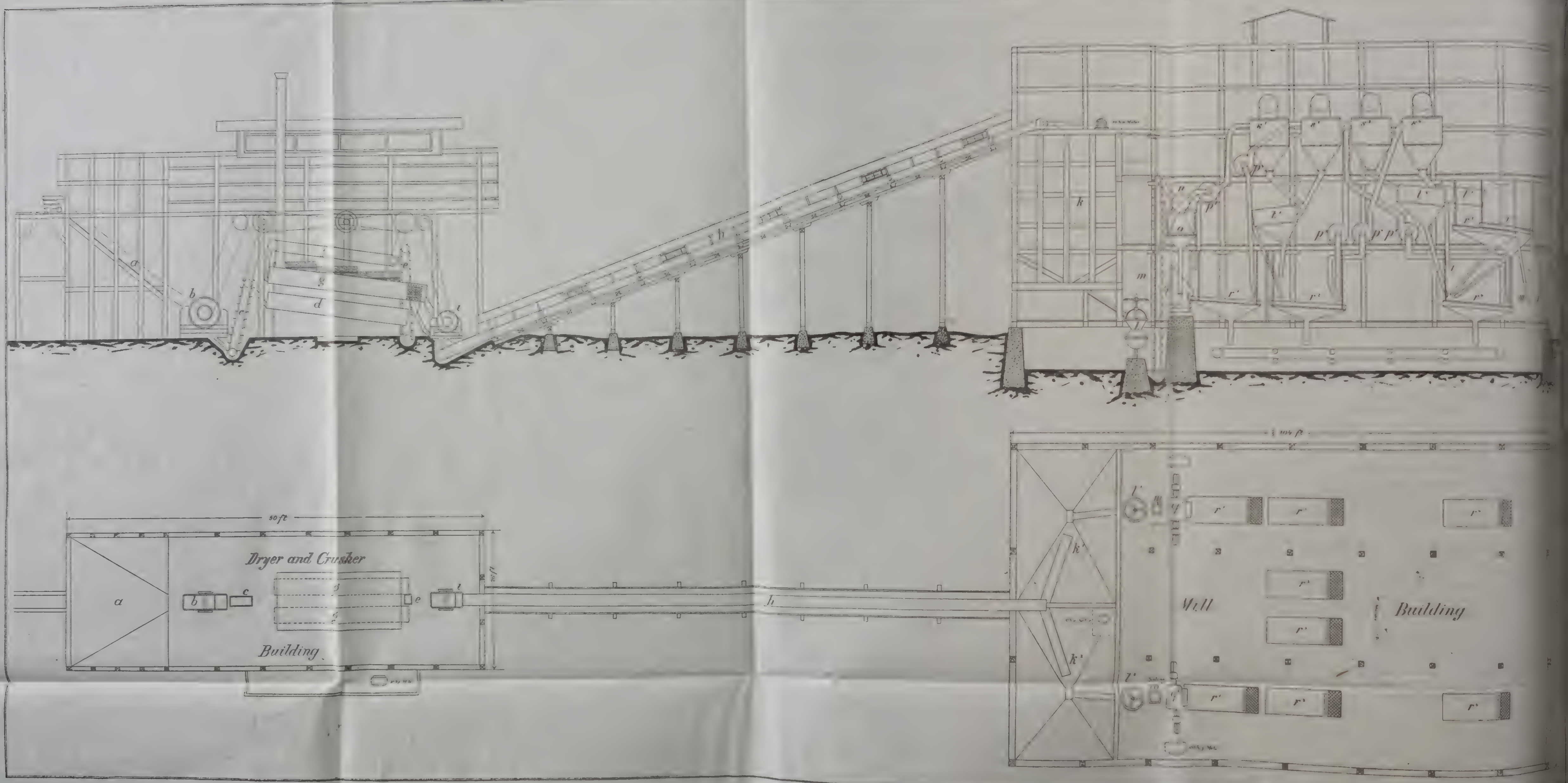


FIG. 36.—Modern Asbestos Separation Plant.

cobbing entirely, and send the whole output of the quarry through the mill. In some mills two qualities are produced; in others four or sometimes five. These factors, combined with other minor considerations, dictate to a certain extent the course of the treatment which has to be followed, and the kind of apparatus to be employed.

In order to illustrate the working of the serpentine method generally adopted, a description of a typical mill is given, which, by reason of its simple construction, will it is hoped, facilitate the study of the principles involved.

A plan showing the arrangement of this mill is given in Fig. 36. No. I and No. II crude are hand-cobbed, and the balance of the asbestos material is sent to the mill for treatment. The serpentine used is massive, and of the usual hardness as found in the Black Lake and Thetford districts. Two qualities are made in the mill with an additional grade out of the tailings of the shaking screens.

First Part of Separation.

All the asbestos rock and fines produced at the mines are dumped into ore bin (a), then crushed in jaw breaker (b) raised by means of bucket elevator (c) to a chute which empties into rotary dryer (d). A bucket elevator (e) raises the material to a belt conveyer (f), transporting it back to the other side of the dryer and delivering it to the second dryer (g). The end of the latter is perforated, and effects a division of the rock into 'medium' and 'rough.' The 'rough' is again crushed in a second jaw breaker, while the 'medium' or undersize falls directly upon the belt conveyer (h), which also takes up all the crushed material from the breaker. The belt conveyer then delivers all the crushed material to two ore bins (k^1) and (k^2), which discharge through an automatic feeder to the Butterworth and Low crusher (1). A bucket conveyer (m) discharges the rock into a fiberizer (n), and after thorough diminution the material falls on a screen (o), where a fan (p^1) takes up all the liberated fibre and deposits the same into collector (s^1). The residue from screen (o) is delivered to cyclones (q); the discharge of the latter is thrown on screens (r^1); here two separations of sand and fibre are effected, the fibre being taken up by fan (p^2) and deposited into collector (s^2), the sand disappearing under the screens into a hopper, which empties on the sand conveyer (u).

Second Part of Separation.

All fibre extracted from the rock is now placed in collectors (s^1) and (s^2). From here, it passes through a grading screen (t^1), having arms within, moving in opposite directions. In this screen two grades are made: long fibre thrown on screen (r^2), and short fibre (or undersize) thrown on screen (r^3). These screens effect a partial separation of the sand from the fibre; the former falling on the sand conveyer (u) and the latter being sucked up and placed into collectors (s^3) and (s^4). From collector (s^3) the fibre is again screened in revolving screen (t^2), the oversize constituting now fibre No. I, and the undersize being again treated on an oscillating screen (r^4) in order to get rid of the sand. What-

ever fibre remains on this screen is taken up by fan (p^5) and is deposited in collector (s^3).

The No. II fibre which is in collector (s^4) goes through the same process of clearing as the No. I fibre, described above, and the final results are a Nos. II and III grade, in addition to the No. I grade referred to.

The following chart, No. I, represents in graphic form a summary of the foregoing descriptive outline of the various stages through which the longer fibre has to pass before it is ready for the market.

There are various other combinations, as will be seen from the mill schemes laid out in charts II, III, IV, and V, and furthermore, new combinations may suggest themselves.

Theoretically, the principles introduced would allow a perfect separation of all the asbestos from the rock, and of the different grades; but practically this is very difficult to accomplish, and is rarely attained.

In looking over the above-mentioned charts, we find that the principal object in the first stages of the process is to eliminate the sand through the shaking screens, and to have as much fibre taken up by the fans as is practically possible. We learn also that many combinations of the crushing machinery are used; but the jaw crusher always forms the initial step, followed by a rotary or Gates crusher; while the last stages of the process are practically the same in all the mills, with very few deviations.

In mill IV, a picking table is inserted between duplex crusher and elevator. These picking tables consist of an endless rubber belt of a width varying between 18″ and 24″; and turning on a wide cone or pulley, with a length of from 12 to 18 feet. Boys are stationed along the belt, picking up the dead rock, long asbestos fibre, and pieces of iron, or rubbish which may have fallen accidentally into the ore. In mines which produce much crude, this arrangement is very important, as the long fibre which was hidden in the rock before breaking can be removed and saved as crude. It is also of equal importance that all the rock which contains no fibre be taken out, to relieve the subsequent operations from unnecessary work.

In the extraction of pieces of steel and iron from the ore, powerful magnets are employed. An effective design for this purpose is in use in some of the Montana mines[1], and its adoption in the asbestos mills of Quebec will not meet with any difficulty. The magnet can either be placed over the conveyer belt, or over the shaking screens. The metal to be removed consists of pieces of steel, bolts, track spikes, and castings from the machine drills. In fact any iron that may get into the ore on its way from the stope to the mill.

The magnet used consists of a cast-iron part (a) 4″ thick, 20″ high, and 20″ wide. It is wound with 19 layers of No. 10 double cotton-covered copper wire (c), with 2,300 turns on each pole. The current used is 5 amperes, at 125 volts. The pole faces (b) are 2″ × 6″ × 24″, and are spaced 6″ apart. The magnet is suspended from a carriage (e) and supported on a track (d) at right angles to

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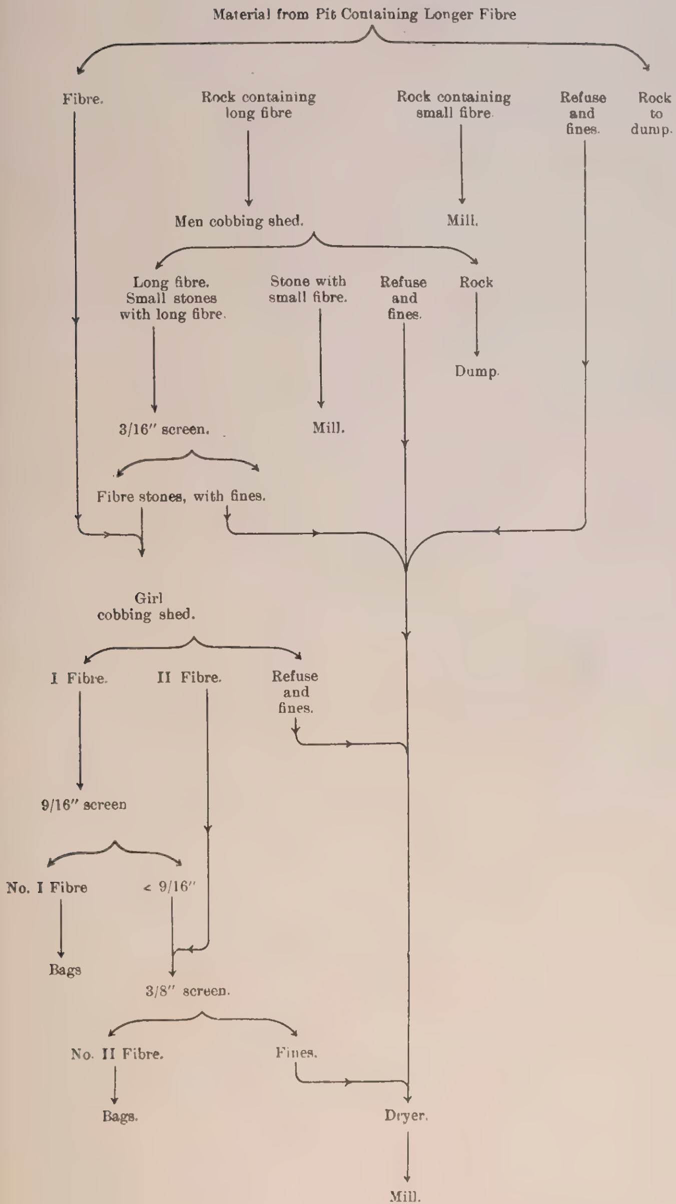
[1] 'The Engineering and Mining Journal,' 1909, page 1238.

CHART I.



Material from Pit Containing Longer Fibre
Fibre.
Rock containing long fibre
Rock containing small fibre.
Refuse and fines.
Rock to dump.
Men cobbing shed.
Mill.
Long fibre. Small stones with long fibre.
Stone with small fibre.
Refuse and fines.
Rock
Dump.
3/16″ screen.
Mill.
Fibre stones, with fines.
Girl cobbing shed.
I Fibre.
II Fibre.
Refuse and fines.
9/16″ screen
No. I Fibre
< 9/16″
Bags
3/8″ screen.
No. II Fibre.
Fines.
Bags.
Dryer.
Mill.

CHART II.

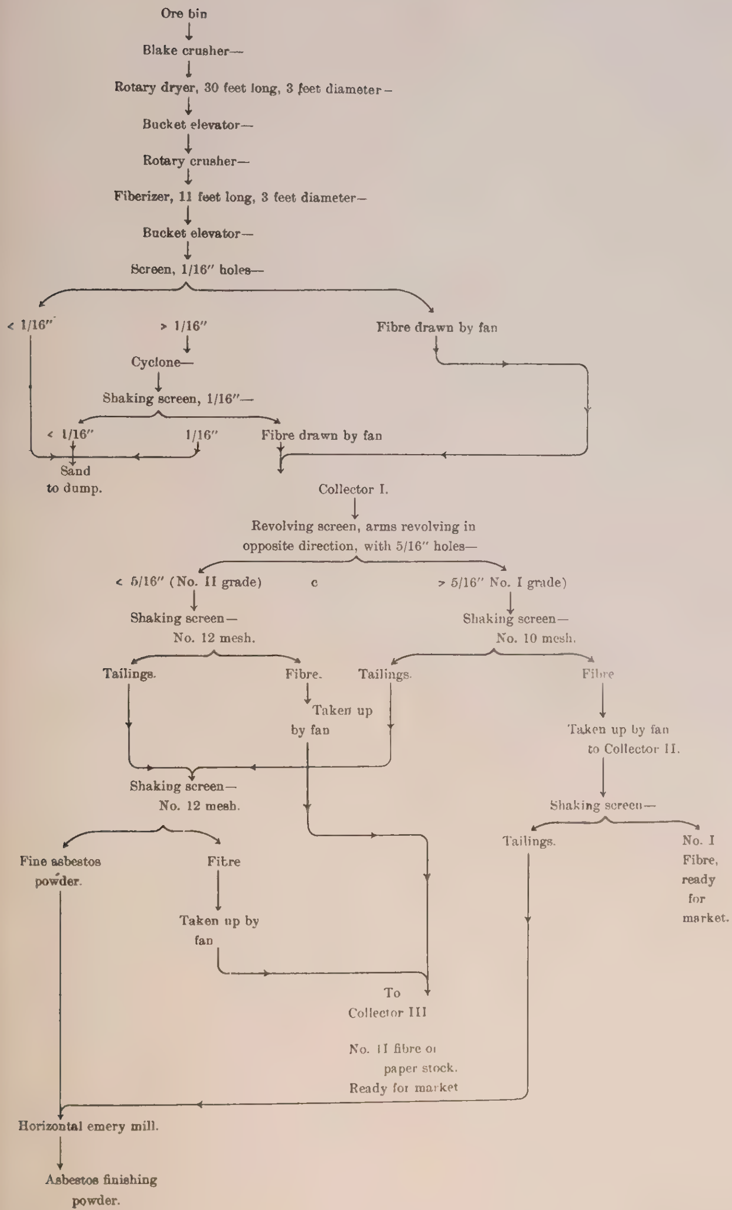
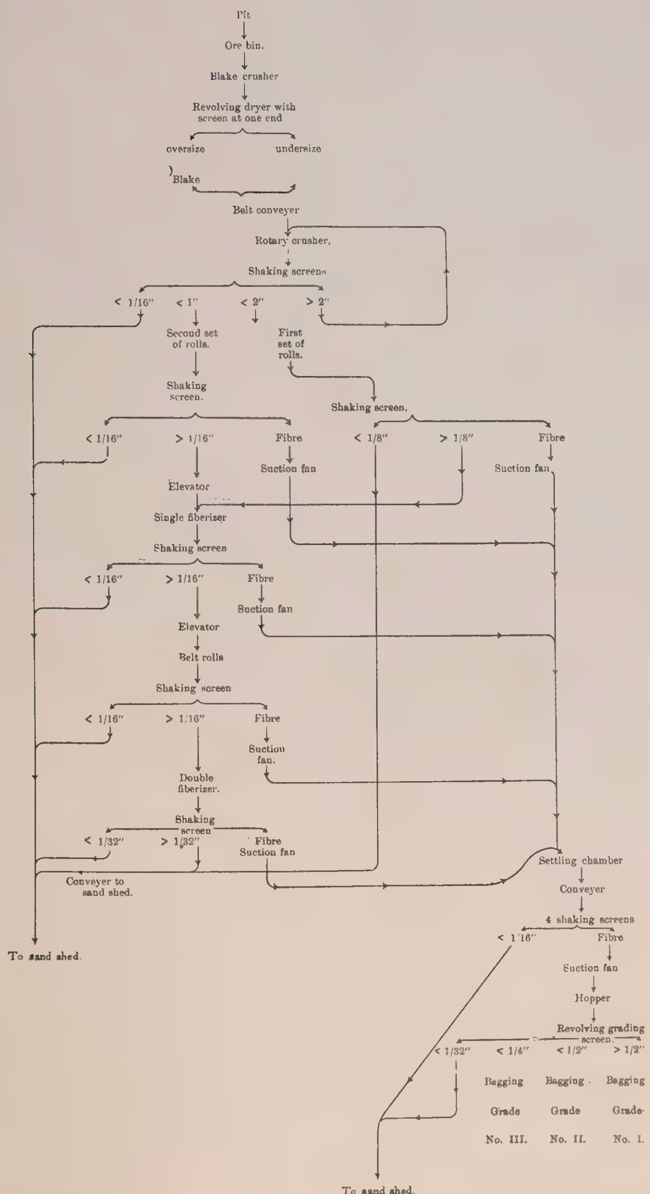
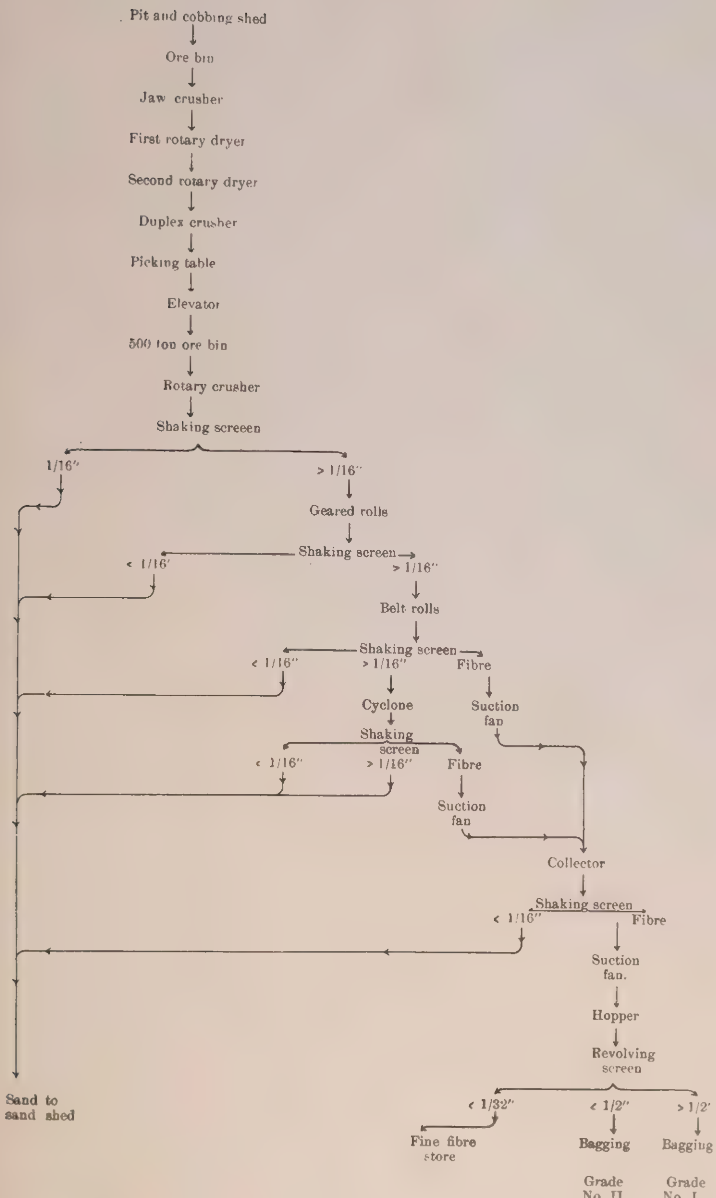

Ore bin
Blake crusher—
Rotary dryer, 30 feet long, 3 feet diameter—
Bucket elevator—
Rotary crusher—
Fiberizer, 11 feet long, 3 feet diameter—
Bucket elevator—
Screen, 1/16" holes—
< 1/16"
> 1/16"
Fibre drawn by fan
Cyclone—
Shaking screen, 1/16"—
< 1/16"
1/16"
Fibre drawn by fan
Sand
to dump.
Collector I.
Revolving screen, arms revolving in
opposite direction, with 5/16" holes—
< 5/16" (No. II grade)
c
> 5/16" No. I grade)
Shaking screen—
No. 12 mesh.
Shaking screen—
No. 10 mesh.
Tailings.
Fibre.
Tailings.
Fibre
Taken up
by fan
Taken up by fan
to Collector II.
Shaking screen—
No. 12 mesh.
Shaking screen—
Tailings.
No. I
Fibre,
ready
for
market.
Fine asbestos
powder.
Fibre
Taken up by
fan
To
Collector III
No. II fibre or
paper stock.
Ready for market
Horizontal emery mill.
Asbestos finishing
powder.

CHART III.



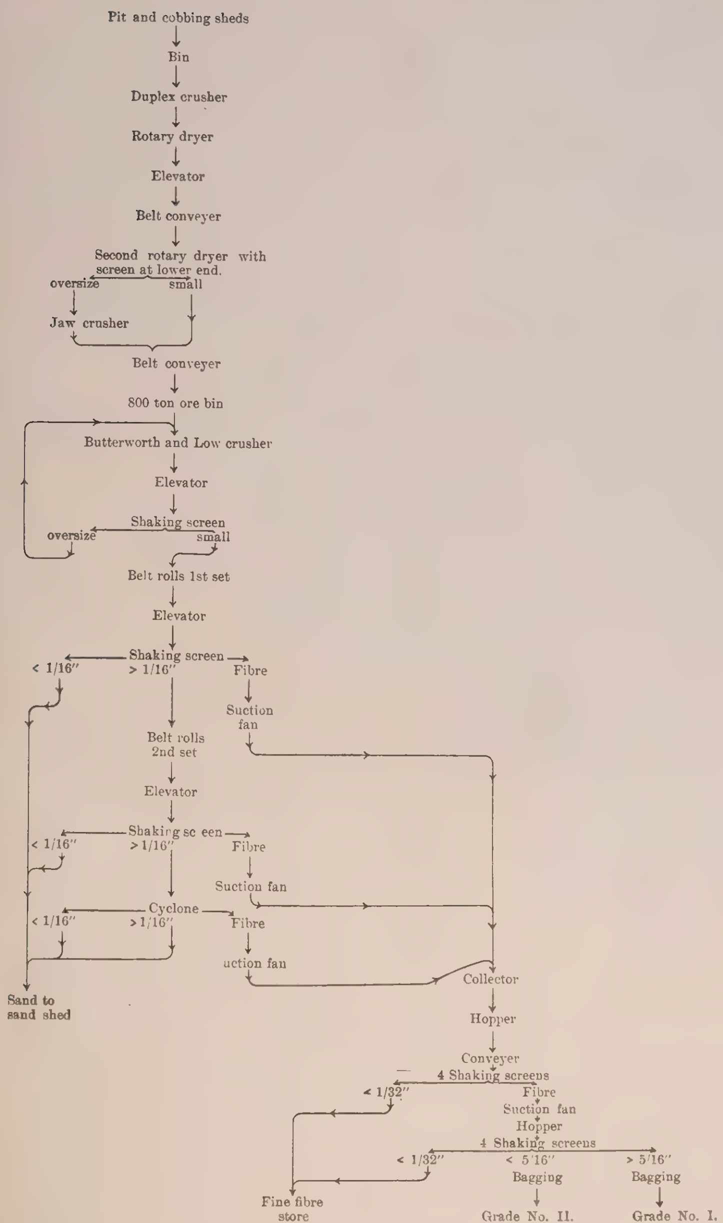
Pit
Ore bin.
Blake crusher
Revolving dryer with screen at one end
oversize
undersize
Blake
Belt conveyer
Rotary crusher,
Shaking screens
< 1/16"
< 1"
< 2"
> 2"
Second set of rolls.
First set of rolls.
Shaking screen.
Shaking screen.
< 1/16"
> 1/16"
Fibre
< 1/8"
> 1/8"
Fibre
Suction fan
Suction fan
Elevator
Single fiberizer
Shaking screen
< 1/16"
> 1/16"
Fibre
Suction fan
Elevator
Belt rolls
Shaking screen
< 1/16"
> 1/16"
Fibre
Suction fan.
Double fiberizer.
Shaking screen
< 1/32"
> 1/32"
Fibre
Suction fan
Conveyer to sand shed.
Settling chamber
Conveyer
4 shaking screens
< 1/16"
Fibre
Suction fan
Hopper
Revolving grading screen.
< 1/32"
< 1/4"
< 1/2"
> 1/2"
Bagging
Bagging
Bagging
Grade
Grade
Grade
No. III.
No. II.
No. I.
To sand shed.
To sand shed.

CHART IV.



Pit and cobbing shed
Ore bin
Jaw crusher
First rotary dryer
Second rotary dryer
Duplex crusher
Picking table
Elevator
500 ton ore bin
Rotary crusher
Shaking screeen
1/16"
> 1/16"
Geared rolls
Shaking screen
< 1/16'
> 1/16"
Belt rolls
Shaking screen
< 1/16"
> 1/16"
Fibre
Cyclone
Suction fan
Shaking screen
< 1/16"
> 1/16"
Fibre
Suction fan
Collector
Shaking screen
< 1/16"
Fibre
Suction fan.
Hopper
Revolving screen
< 1/32"
< 1/2"
> 1/2'
Fine fibre store
Bagging
Bagging
Grade No II.
Grade No. I.
Sand to sand shed

CHART V.



Pit and cobbing sheds
Bin
Duplex crusher
Rotary dryer
Elevator
Belt conveyer
Second rotary dryer with screen at lower end.
oversize
small
Jaw crusher
Belt conveyer
800 ton ore bin
Butterworth and Low crusher
Elevator
Shaking screen
oversize
small
Belt rolls 1st set
Elevator
Shaking screen
< 1/16″
> 1/16″
Fibre
Suction fan
Belt rolls 2nd set
Elevator
Shaking sc een
< 1/16″
> 1/16″
Fibre
Suction fan
Cyclone
< 1/16″
> 1/16″
Fibre
uction fan
Sand to sand shed
Collector
Hopper
Conveyer
4 Shaking screens
< 1/32″
Fibre
Suction fan
Hopper
4 Shaking screens
< 1/32″
< 5/16″
> 5/16″
Bagging
Bagging
Fine fibre store
Grade No. II.
Grade No. I.

the belt. When a number of pieces of iron are collected on the magnet, the entire apparatus is moved to one side, the current cut off, and all the iron is dropped to the floor. The magnet is suspended 6″ to 8″ above the belt, and is

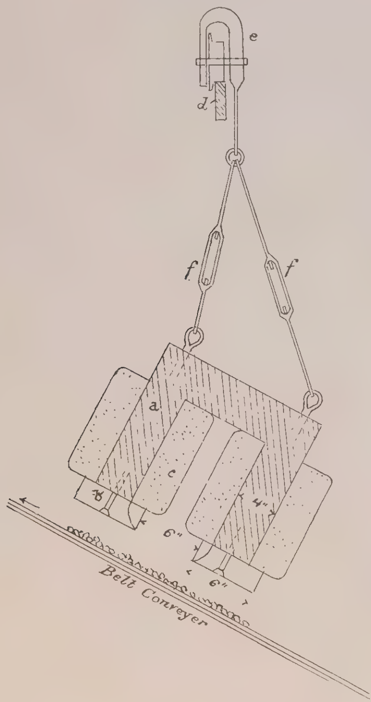


FIG. 42.—Magnet for picking steel from ore.

adjustable by the means of turnbuckles (f). This magnet will pick up pieces of steel weighing as much as 10 pounds; this prevents trouble and breakage at the rolls.

In designing a mill, due attention must be given principally to the crushing department; since mistakes made here have very serious results, either in the quality of the fibre produced, or in the low percentage of extraction. Experience shows that crushing of the rock before drying is absolutely necessary in order to ensure complete drying of the rock in wet seasons. As a general rule, one or even two Blake crushers are placed before the dryer, and one at the discharge end of the latter. The drying and most of the coarse crushing is now all done in a separate building; because, when placed in the upper part of the mill building, the power toggle movement of the jaw breaker causes a heavy vibration in the structure of the building, hence, heavy construction is necessary. A new departure in mill construction may be seen in the plant of the Robertson Asbestos Company, between Robertson and Thetford stations. Here the whole

plant is divided into three parts: the dryer and crusher building; the re-crusher; and the cyclone building. This is the first time that this division in three separate departments has been made.

There are other new noticeable features in this mill. The rock coming from the dryer passes through two gyratory and one rotary crusher, having shaking screens between, for the purpose of abstracting, by means of suction, whatever fibre there has been liberated through crushing. We notice that the rock passes through not less than five different crushing apparatus before it enters the cyclone; and three in nearly all other mills; it is only exceptionally that four crushing machines are used for the same purpose. It is urged in support of this innovation that the cyclone, which receives only ore of uniform size—smaller than a walnut—will treat a far higher tonnage of ore, doing at the same time, better and more uniform work.

There can be no question that through the employment of the designs indicated above, the efficiency of a mill is increased; while much breakage in the different pieces of apparatus—especially in fast revolving machines like the cyclone—is prevented.[1]

Of the fiberizing machines the cyclone appears to be the most extensively used in the mills. In some of the newer mills other machinery has been introduced to take the place of the cyclone. This is shown on chart for mill No. III, where the fine crushing is represented as being done by two pairs of belt rolls, in connexion with single, and double cylindrical, fiberizing apparatus. In another mill the material passes twice in succession through a set of rotary crushers and a beater of recent design; the construction of which is kept a secret. It is claimed for this new departure that the fibre is not torn up so much, and that the repairs are less, and not so costly as those in the cyclone machines.

The different grades of fibre are, as a rule, made in most of the mills at the end of the process, by sizing in shaking screens, or in revolving screens with arms moving in opposite directions. A new departure in the extraction of the fibre from the screen, and the elimination of the sand, was made several years

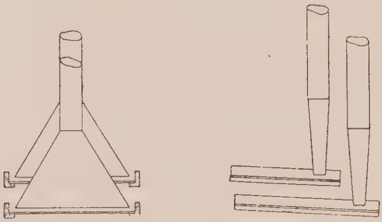


Fig. 43.—Double Shaking Screen.

ago in a mill of new construction. The experiment failed; but for the novelty of the idea, and for the purpose of calling attention to the mistakes involved in its application, the device is again described and illustrated. The material after being crushed successively in a jaw and rotary crusher, and a beater, falls on a

[1] Since writing the above several changes in this mill have been made, and at the same time the capacity increased from 2 to 6 cyclones.

Milling plant at the Beaver quarries of the Amalgamated Asbestos Corporation, Thetford, Que.

double shaking screen, as illustrated in Fig. 43: the upper one having $\frac{7}{16}''$ and the lower one $\frac{1}{16}''$ mesh, allowing the sand to pass away. The fibre is graded in this way into No. I and No. II. Each grade is taken up at the end of each screen by suction fans, and deposited in separate collectors. The overflow from both screens passes again through a rotary crusher and beater and a double screen as before; while the two grades of fibre, so produced, are taken up and deposited in collectors. The principal trouble in this device was, the difficulty of gaining access to the lower screen: it was blocked so frequently that its usefulness soon vanished.

The sand from all the shaking screens falls generally into a long hopper, having a rubber belt conveyer at the bottom, which transports all material to the outside. Where the dumping ground is not on the same level with the mill, the sand is carried by conveyers into elevated sand-sheds or large reservoirs, from which cars are loaded and sent to the dump.

At the British Canadian quarries the sand is transported through a 658 ft. rubber conveyer to the dump; from thence it is carried away through sluicing; a turbine pump actuated by a 75 horse-power electric motor placed at the river bank furnishing the necessary water through a 6″ main 1,000 feet long, to the top of the dump.

In the mills at Danville the bulk of the sand and tailings from the shaking screens is manufactured into *asbestic*: a fine asbestos powder which enters now largely into the construction and inside finish of fireproof buildings.

In one of the largest mills recently erected, all the tailings are pulverized in giant, vertical, Emery mills.

GENERAL FEATURES OF THE MILLS IN THE DISTRICT.

With a few exceptions, the mills visited by the writer are located near the quarries: that is, within 500 feet; indicating that the transportation of the ore to the mill is a most important factor. In the general arrangement of all the newer mills due consideration has been given to the dumping ground, with a view to preventing the covering of valuable ground. For this reason the mills have been built away from the quarries.

With regard to the sites on which mills are built, we may distinguish between (1) a sloping or terraced site (Fig. 44); a flat site (Fig. 45). In the

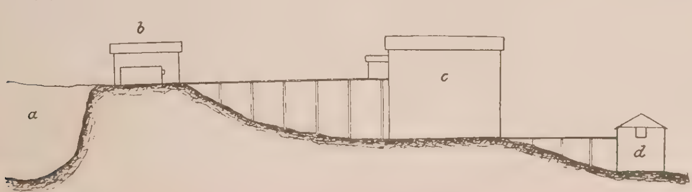


FIG. 44. -Typical Sloping Mill.

(a) Pit. (c) Mill.
(b) Dryer. (d) Storehouse.

former case advantage is taken of the sloping condition of the ground, all material being conveyed by gravity, and heavy elevators are few. An example of this

kind is the old mill of the Union quarry, now of the Black Lake Consolidated Asbestos Company at Black Lake.

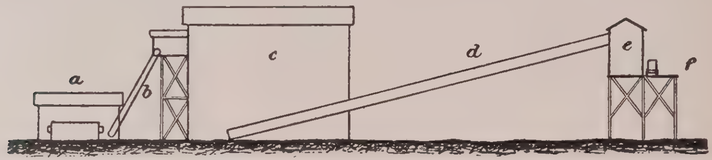


FIG. 45.—Typical Flat Mill.

(a) Dryer. (d) Sand conveyer.
(b) Elevator. (e) Sand shed.
(c) Mill. (f) Elevated track.

Mills on the flat ground, however, are the common rule. The disadvantages are, that more elevators are required; which wear out rapidly; causing stoppages of the mill on account of breakage, and annoying the mill man.

An asbestos separation plant is usually designed in the form of a three or four story building. The ore is received in a large ore bin, placed in the upper part of the building, or in an annex: allowing the ore to pass through the crushing machinery by gravity; elevators being used between the apparatus for middlings and for recrushing. In the majority of cases, however, the ore passes on straight without recrushing in the same apparatus. Sometimes all the fine crushing apparatus and fiberizers are placed in one line and on one floor, as at the mill of the Johnson Asbestos Company at Black Lake. Small elevators convey the material from one apparatus to another; and it is claimed for this arrangement, that the machinery can be watched better, and is more accessible than when placed on different levels. The screens receiving the material from the crushers are, as a rule, placed all on one floor, for the purpose of greater accessibility; while an endeavour is made to do the same in all the newer mills with the shaking screens for the fibre.

In mills of recent construction—in order to avoid complete stoppage caused by breakage of machinery or otherwise—the whole milling plant is divided into two portions, and constructed on precisely the same lines; but run independently of each other. This innovation was noted in the mills recently built at East Broughton and at the 'British Canadian' quarries. In the latter this principle is even carried further: the two sections are again divided into different parts, each one embracing a certain group of machinery run by special electric motors. In the mill proper the six cyclones are all placed in one line on one side of the building; the electric motors actuating the same being all in one separate compartment close by. This is an arrangement of apparatus to be recommended on account of its great accessibility, uniform division, and the protection of the motors against flying dust. (See Fig. 46.)

Plant.

In addition to the mill itself, auxiliary buildings are used. The boilers are generally placed in a separate building; the mill engine and all accessory mach-

Bunch of fiberized asbestos, ready for the market.

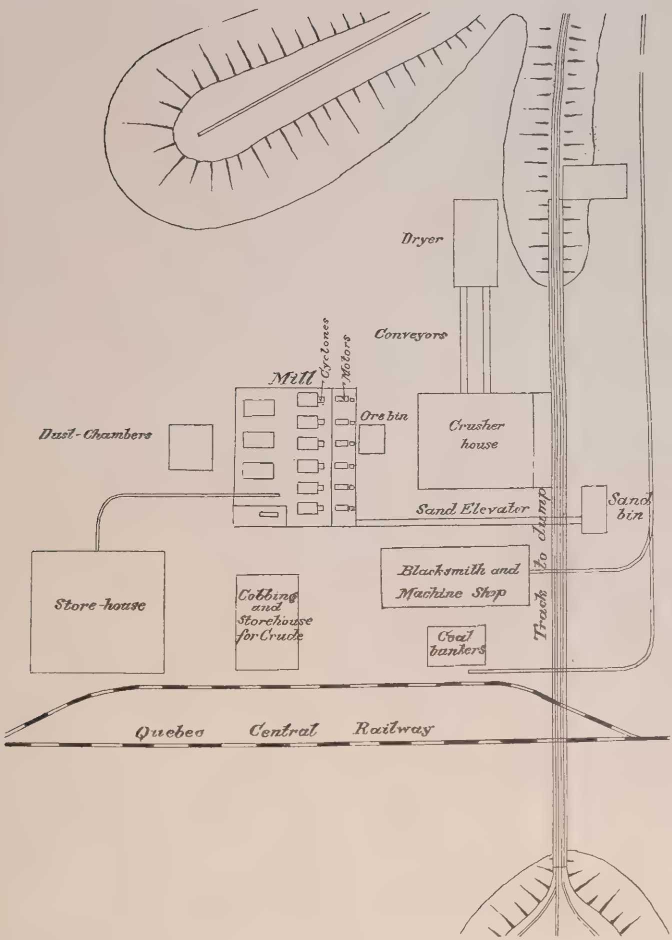


FIG. 46.—Milling plant of the British Canadian Quarries (Amalgamated Asbestos Corporation.)

inery—such as dynamos and compressor—in a shed adjoining the mill; while the rotary dryer, on account of the danger from fire, is located in a shed at some distance from the mill. As a rule, a carpenter, millwright, and machine repair shop is run in connexion with the mill.

The store houses are all separate buildings with rail connexion. The plant of the British Canadian Quarries at Black Lake, is housed in six buildings (Fig. 46): a dryer and a crusher building; the mill proper; the store house; finishing cobbing-shed; the machine repair shop, and coal bunkers.

Most of the buildings are constructed of wood on solid concrete foundations; and are either boarded vertically and the cracks battened, or they are double-boarded: the boards covering joints in every case. The new mill of the 'Dominion' quarries is covered with asbestos protected metal. The new office and mill buildings of the Bell quarries are covered with asbestos, slate, and shingles, manufactured by the Keasbey and Mattison Company, of Ambler, Pa.

The roofs of the mills are generally made of tar-paper, and galvanized iron, or sometimes of asbestos shingles; thereby saving high premiums for insurance. One mill is covered with corrugated iron; but the disadvantage arising out of the application of the latter is, that the building is somewhat difficult to heat in winter, owing to its high conductivity. In some of the newer mills the dryer buildings are made of brick, with iron roof; or entirely of iron, as at the Beaver quarries.

Some mills are painted, others are not. In the former case red or grey mineral paint is the kind most used, which not only aids in preserving the wood from decay, but also protects it, to some extent, from fire. All mining and milling plants are now provided with the necessary appliances to guard against destruction by fire. For this purpose duplex pumps are kept constantly under steam, while hydrants and hose are placed at different points throughout the mill. The Asbestos and Asbestic Company, at Danville, having suffered from a disastrous fire in the year 1900, which destroyed their milling plant, keep a large duplex pump with a capacity of 1,000 gallons per minute steadily under steam, in order to be prepared in case of fire. At the mill of the British Canadian quarries a turbine pump, delivering 500 gallons of water per minute, and stationed at a distance of about 800 feet on the river bank, distributes the water through 4 hydrants all over the works.

Electricity as a Motive Power

The great advance made in the science of electricity, together with the facilities which nature has provided in the form of water power—especially in the Province of Quebec—has opened up an immense field of application as a motive power in mining and milling. When the St. Francis Hydraulic Power Company, in 1904, had finished the building of a power station at the rapids of the St. Francis river, about six miles distant from Black Lake, and the erection of a transmission line to the asbestos district, the feasibility of such an undertaking was questioned; since—so it was argued—all the quarries were provided with adequate steam power for all their needs. The conservatism of mining engineers

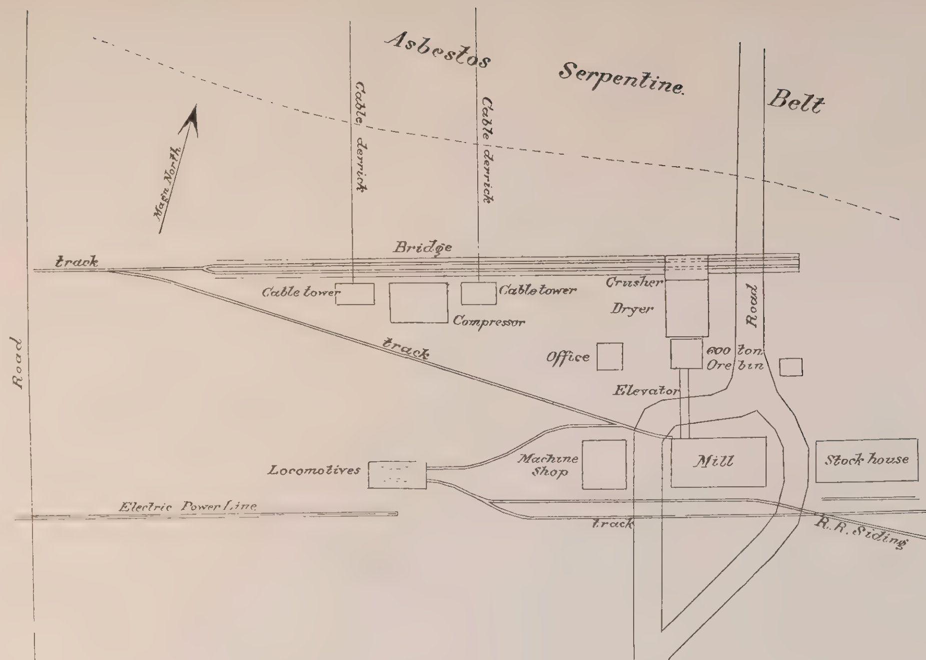


Fig. 47.—Surface plant of the Frontenac Asbestos Mining Co. at East Broughton, Que.

and mine managers at once asserted itself; they reasoned that they could not afford to install new machinery, however good it might seem, having to consider before all other things, the getting out of the mineral; unless they were quite sure of the superiority of electricity over steam; and unless they were also quite sure that this innovation would not interfere, even temporarily, with the output. The American Asbestos Company—now the Amalgamated Asbestos Corporation—of Black Lake, were the first concern to make use of hydro-electric power in the running of their mines and mills. They at once realized the enormous advantages which electric energy has over steam power; especially in a district where the fuel question was a constant source of trouble to those who were responsible for the economical running of large industrial establishments. Wood as fuel was getting very scarce, while the supply of coal was becoming very unsatisfactory; indeed, it was no unusual occurrence, that a mine had to suspend operations during the winter, entirely owing to the lack of that commodity. The prohibitive cost of coal fuel; the long haul of the latter from Pennsylvania; the blockades on the railways in the winter; as well as the annoyances through coal miners strikes, render the use of coal almost prohibitive; hence the advent of electric energy as a motive power has removed almost all these constant annoyances to which the works were periodically subjected when coal was used. That the American Asbestos Company had made no mistake from the start, was clearly evidenced by the adoption of electric motive power for their mines and mills by other operating companies. It was even soon realized that the limited supply of electricity was not sufficient for requirements and the increased demand brought a new electric company into the field, namely, the Shawinigan Power Company. This Company owns and operates an extensive water power in Shawenegan, at a distance of over ninety miles from Thetford on the north side of the St. Lawrence river. Their new transmission line cuts right across country; strikes first the mines west of Coleraine station, and extends via Black Lake, Thetford, Robertson, as far as East Broughton, a total distance of 90 miles.

Besides the elimination of all the disadvantages enumerated above, the cost per horse-power per year produced electrically, is cheaper than produced by steam; the former is now $25 per horse-power per year; whereas the cost in steam plants—where the best steam saving appliances and devices are installed—is $35; and in plants where no such appliances are in use, as high as $47.

The main advantages of electricity, as compared with steam or compressed air, may be summarized as follows:—

The difficulty of conducting steam, compressed air, or hydraulic pressure, over long distances, and the great losses which are invariably incident to their transmission, are sufficiently well known. It is in this respect that electricity is pre-eminent in its economic advantage: namely, the ease and simplicity with which it can be transmitted over long distances—either above or under ground. The transmission lines are flexible, and much cheaper than either of the three forms of energy mentioned; while the current can be subdivided into any desired form without corresponding increase in the losses. The effective condition of the line can always be easily controlled from the central station; whereas losses

Mill at the Dominion quarry of the Amalgamated Asbestos Corporation, Black Lake, Que.

by leakage with other forms of transmission are unavoidable—even with the best supervision. Owing to the flexibility and facility of the application of the electric current to large as well as to small machinery, it lends itself pre-eminently to all the motive wants in mining work. Electrical apparatus are generally less bulky and less costly than power machines which use a different form of energy. They, therefore, do not require expensive foundations, but can be set up, almost anywhere, within easy reach of the mechanical appliances which they drive. Moreover, the efficiency of electric machinery is high, so that the energy is used to better advantage. The main point of view, of course, in the planning of an electric central station for mining purposes, is the possibility of distributing the current in such a manner that all the machines which are to be driven electrically can be served in the best possible manner in view of their location and the work which they have to perform.

Owing to the convenience of applying electric energy to all kinds of mining machinery, it has been made possible—on account of the ease with which the electric current can be measured—to ascertain exactly the amount of power absorbed by the various mining machines, under different conditions of operation. This is an important feature, and makes it possible to calculate the reserve capacity to be allowed with much greater accuracy than formerly, when rule of thumb methods were in vogue.

'Compagnie Hydraulique St. François.'

The power house of this Company is located on the St. Francis river, 2½ miles from D'Israeli station. It is a solid brick building, with heavy concrete foundations, the tail-race being cut in solid rock.

Two generators of 1,000 horse-power each, and six transformers (2,400 to 15,000 volts) are installed. During the summer season an auxiliary steam plant of 1,700 horse-power, and a third generator of 1,000 horse-power, will be added. The length of the transmission lines is as follows:—

From D'Israeli to Black Lake (6 No. 4 wires, 15,000 volts).. ..	8 miles.
From Black Lake to Thetford (3 No. 4 wires, 15,000 volts).. ..	4 "
Branch lines in Black Lake and Thetford mines (6 No. 4 wires, 2,400 volts)..	4 "
Total length of transmission...	16 "

Two transformer stations have been built: one in Thetford and the other in Black Lake. The Thetford station contains four transformers, 250 kw. each, housed in a solid brick building; and the Black Lake station, six transformers of 250 kw. each, in a building constructed of wood and lined inside with asbestos slate. The step down in these transformers, which are equipped with automatic switches, etc., is from 15,000 to 2,400 volts.

The Shawinigan Water and Power Company.

This Company controls the second largest water-power plant in the Dominion. In its vast development power, and possibilities of further enlargement, Shaw-

inigan falls is surpassed only by Niagara falls. Already 100,000 horse-power is being developed, and of this, 10,000 horse-power is reserved for the supply of the asbestos mines in the Eastern Townships of Quebec. The Shawenegan falls are located on the north shore of the St. Lawrence river, at a distance of twenty-two miles from Three Rivers: forming the connecting link between the upper and lower portion of the St. Maurice river. The first sub-station along the transmission line, connecting the mines with the falls, is located at Victoriaville, at a distance of seventy miles from the falls. From here, two separate transmission lines branch off: one supplying the mines near Asbestos, at a distance of twenty-five miles from the falls; and the other supplying Thetford, as the distribution centre for almost all the asbestos mined in the district, at a distance of forty miles. From Thetford, two branch transmission lines have been constructed: one to East Broughton, twenty miles long; the other to Coleraine, via Black Lake, sixteen miles long. The sum total of the distances to which electric energy is transmitted from Shawenegan falls to the various asbestos mines in the Province of Quebec is 171 miles.

There are sub-stations at Three Rivers, Victoriaville, Asbestos, Thetford Mines and Black Lake, Coleraine, Robertson, and East Broughton. The voltage carried on these lines is 50,000; but crossing the St. Lawrence river the transmission line is composed of three submarine cables, the voltage being reduced from 50,000 to 25,000, followed by a subsequent step up to the original 50,000. At the mines, this voltage is reduced to 2,400, and power is delivered to consumers as a three-phase, alternating current 2,200, 30 cycles.

Power is contracted for at a rate of $25 per electric horse-power, for all the year round.

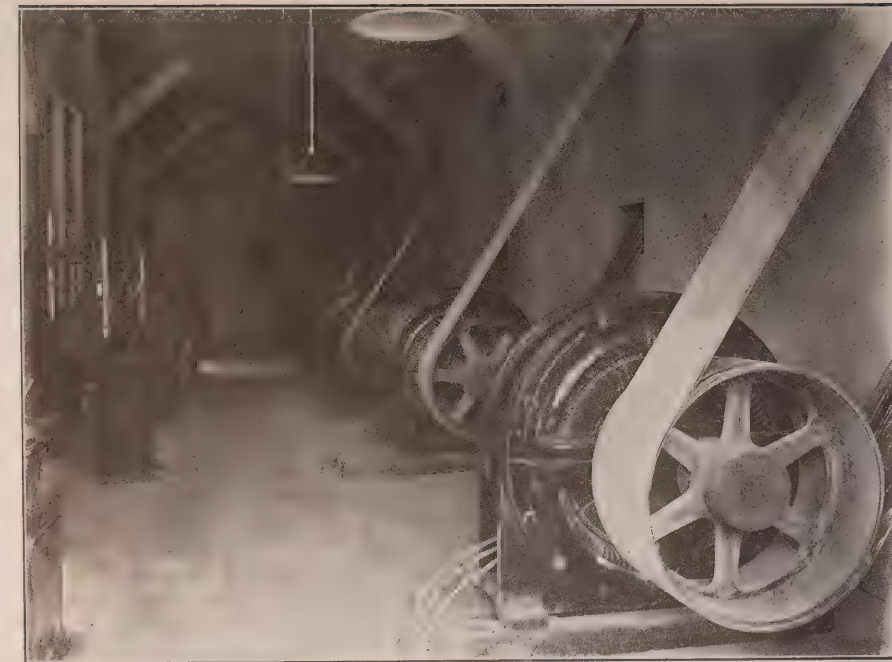
Motors.

Nearly all the mills built prior to the advent of the hydro-electric age, and which are now driven by electric energy, were originally laid out and constructed for steam power, hence, had to be altered to suit the new conditions. For this reason the distribution of power in those mills, through electric motors, is necessarily not of a very economic and advantageous character, and many losses are incurred, caused by faults in transmission. In some of the mills one large motor serves to drive the mill proper; while in others the principle of power division is carried to an extreme degree. For instance, in one mill of a capacity of 500 tons, 12 motors were counted—the largest being 125 horse-power capacity.

It would serve no practical purpose to consider the matter of power distribution through the mill, since this depends largely upon the objects in view; the division of the mill into units, and many other factors.

Amount of Power Used.

The horse-power required per ton of ore treated in a double shift varies, of course, in the different mills with the quantity and kind of rock treated; with



Arrangement of electric motors for cyclones in the British Canadian mill of the Amalgamated Asbestos Corporation, Black Lake.

the apparatus employed; and it will even vary in the same mill, owing to slight changes of velocity or of the speed of feeding and discharge, and also in the size of the material fed to the breakers. For these reasons, average figures cannot be applied to every individual mill, and they can, therefore, be only of general value.

Most of the mills have sufficient reserve capacity to obviate the necessity of forcing any of the machinery, and even permit the temporary suspension of a machine for adjustment and repairs.

Deduced from the data at the disposal of the writer, it appears that for every ton of rock crushed and treated, 1 to 1·25 horse-power is, on an average, required; so that a mill treating about 250 tons of asbestos rock in two shifts per day requires a capacity of the machinery of from 250 to 310 horse-power; providing at the same time a sufficient reserve capacity. From 75 to 90 per cent of the power originally supplied is used in crushing alone; the balance is consumed in screening and blowing. The capacity of a mill is generally expressed in the number of cyclones (or their equivalent) installed: each cyclone having an average crushing capacity of about 120 tons per double shift. Most of the mills in operation have two and three cyclones; the largest mill in the district contains eight cyclones.

Cost of Labour in Mills.

The cost of labour employed in the mills varies as much as the power necessary to run them. While some mills are laid out and constructed so that little attendance is necessary; others are cramped in room, the machines employed are not easily accessible, and the general machinery is such, that it requires extra help to preserve its integrity.

If exact figures in this respect were at hand, they would show that the number of tons treated per man varies greatly even in mills of practically the same construction.

This variation depends upon the following factors:—

(1) The difference in the care exercised in the manufacture of the different grades.

(2) The size of the plant; since a large mill can always be run with less labour per ton, and hence more economically than a small one.

(3) On the favourable location and design of the mill to minimize labour costs.

However, in the absence of accurate data on all the mills, the two following examples are given, showing the labour employed in mills which have a fairly modern plant, and working under ordinary conditions.

One mill treats 150 tons of asbestos rock per day, or 75 tons in one shift. The labour employed per shift to run this plant is as follows:—

1 engineer	$ 2 25
1 fireman	1 75
1 millwright	4 50
1 foreman	2 25
1 oiler and helper	1 75
3 men feeding crusher, $1.50	4 50
1 fireman on dryer	1 50
1 sandman	1 50
3 men for bagging, $1.50	4 50
13 men	$ 24 50

The total amount expended on wages is, therefore, $24.50, or, $24.50 ÷ 75 = 0.33 per ton of milling rock. This mill produced as an average, 7 tons of fibre, hence the labour expended amounted to $24.50 ÷ 7 = $3.50 per ton.

In another mill 250 tons of rock, on an average, are treated in two shifts. The labour employed is as follows:—

1 engineer	$ 2 25
2 firemen	3 50
1 millwright	4 50
1 foreman	2 25
3 helpers, $1.50	4 50
2 sandmen, $1.50	3 00
3 men feeding crusher, $1.50	4 50
2 men for dryer, $1.50	3 00
4 men for bagging, $1.50	6 00
19 men	$ 33 50

The average cost of labour in this case amounted to $33.50 ÷ 125 = 0.29 per ton. The mill produced, on an average, 10 tons of asbestos fibre per shift: the cost of labour amounted, therefore, to $33·50 ÷ 10 = $3.35 per ton.

The capacity of a mill and the quality of the product depend largely upon the intelligence and reliability of the men employed in the various departments. A saving made in the wages may be more than offset by losses in the efficiency of the machine, due to ignorance or neglect.

So many various considerations enter into the successful accomplishment of the separation of asbestos from the rock and the production of very fine grades of fibre, that it would be out of place to generalize on the subject of wages expended in the mills.

Percentage of Milling Material in Total Rock Mined.

There is considerable variation in the quality of the rock mined. While one mine may deliver a high percentage of crude and a poor milling rock, another may not produce any crude at all, yielding, however, a milling material rich in fibre. The quarries at Black Lake and Thetford produce crude and mill fibre; whereas those at East Broughton deliver mill fibre only. It is evident from the facts presented in the chapter dealing with the occurrence of the mineral that the percentage of milling rock in the total rock mined varies from day to day in

every quarry; unless special precautions are taken to mine only a certain chute of ore of known quality. The mill has to depend upon the quarry for a regular supply of ore, and any changes in the condition of the latter are felt at once in the mill.

In the Broughton district, where the slip fibre occurs, almost all the rock mined goes through the mill; whereas in all the other or 'vein' fibre quarries the lowest percentage of asbestos milling rock of the total rock mined is 20 per cent, the highest 80 per cent. On an average, the milling rock furnished by these quarries may be taken as from 30 to 60 per cent of all the rock mined.

Percentage of Fibre in the Milling Rock.

The variation in the percentage of fibre in the milling rock is just as great as in the percentage of milling rock in the total rock mined. In the Thetford and Black Lake quarries an extraction of from 6 to 10 per cent of the milling rock is effected in the majority of mills. There are exceptions of higher extraction, but generally speaking, rock of fairly good milling quality should yield a percentage within the above-mentioned limits. In the Broughton or slip fibre quarries, an extraction of from 7 to 12 per cent is made. A considerable quantity of the fibre produced is somewhat shorter than that produced in the Thetford quarries; but as previously stated, all the rock mined passes, generally, through the mill.

Percentage of Crude in the Total Rock Mined.

The production of crude has lessened to a very large extent, owing to the general introduction of mechanical treatment; and is practised now, only in a few mines that work on richer ground. In these quarries—as a general rule—the quantity of crude of Nos. I and II quality can be put down as from 0·25 to 0·75 per cent of the total rock mined; but it is known that one or two quarries produce a somewhat higher percentage than this.

From 1901 to 1909 inclusive, according to statistics furnished by the Quebec Bureau of Mines, there were produced:—

35,544	tons of	crude
125,423	"	mill fibre
269,688	"	paper stock
430,655	"	asbestos.

According to these figures the production of crude amounted to 8·25 per cent of the total production.

Grades.

The output of the quarries is, to a certain extent, differentially graded. As to the rule, there are only No. I and No. II qualities made; the former measuring about 1″ and the latter from ½″ to 1″ in length.

The milling fibre is generally divided into three grades; but sometimes, additional grades are made, having special qualities. The qualities of the general

run are designated as follows: first grade (spinning fibre); second grade, and the third grade, (paper stock).

The percentage of extraction of the different grades in the mills varies according to the demands made for certain qualities. Some quarries, after extracting all the very short fibre, produce what is known as a run of mine grade; while others make two or three, and others again, even five grades. For this reason it would be difficult to give figures of the percentage extractions; but according to the above cumulative statistics, the quarries produced for a period of eight consecutive years:—

125,423 tons of mill fibre
269,688 tons of paper stock

Total 395,111 tons,

or, expressed in per cent:—

32 per cent mill fibre.
68 " paper stock.

Cost of Mill and Mine Equipment.

The cost of a mill depends largely upon its capacity; upon the general design and internal arrangements of the mill buildings for the purpose of economizing labour: thus simplifying the whole milling plant; upon the character of the mill site; heaviness of construction; care in the manner of erection; and finally, upon the cost of the material and machinery—which fluctuates from time to time. The cost increases, of course, with the capacity; but not in the same proportion. The cost per ton of ore treated becomes less with an increase of the capacity; since such items as insurance, taxes, management, and general business expenses increase comparatively very little with the capacity. Further, the increase of the capacity brings down the cost per ton, and allows poorer ore to be milled. This will, of course, cut down the average percentage extraction of asbestos, and at the same time the profit per ton; but the total profit with the larger quantity and the lower yield per ton will be greater than the total profit with the smaller quantity and the higher extraction per ton. There is also considerable saving in a large mill from buying supplies in large quantities; and from the making of repairs on a large scale. The general design is also an important factor, because the method of drying and crushing varies with the conditions of the quarries as well as with the commercial objective regarding the production of certain grades in view.

Another important factor in the construction costs is the mill site: a steep slope will require expensive masonry; which is not required when the mill is built on flat ground. Upon the location of the mill depend also the cost of haulage per ton to the mill, and the disposition of the mill tailings.

The details in the interior construction of the mill, as well as in the selection of the materials used, are also important items. Some mills use heavier machinery than others, and require for this reason, heavier foundations. Further, mills built at a time of general prosperity will cost more than if built at a time

Mill No. 1, King's quarry, of the Amalgamated Asbestos Corporation, Thetford, Que.

of general depression. They will also cost more when they are required to be finished within a short specified time, than when reasonable time is allowed. However, an extremely long time used for construction may be objectionable on account of the loss of interest on the capital invested.

Only one example of the cost of a mill is given; and while the writer believes that the data submitted are reliable, it is to be used merely as an approximate estimate of the cost of a new mill.

This particular mill is built large enough for the installation of four cyclone units; but for the beginning only two cyclone units are installed, having an initial capacity of 240 tons per day of 24 hours. The ground upon which the buildings stand is fairly flat; the distance from the next railway station being one mile.

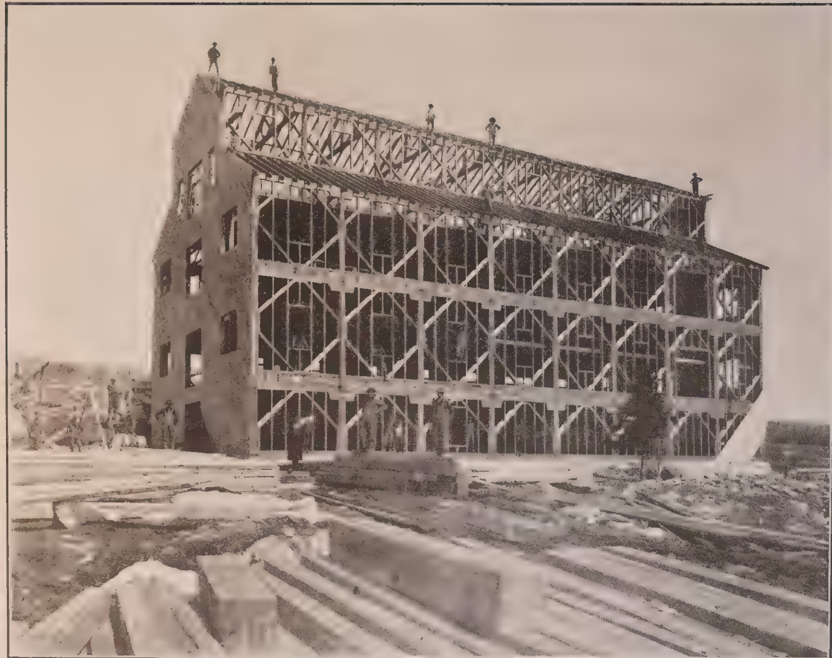
Clearing ground, excavation, and leveling..		$ 600
Concrete foundations: for mill building.. ..	120 cubic yards	
" piers..	6 "	
" crackers..	2 "	
" cyclones..	5 "	
" ore bin..	4 "	
" dryer and crusher	10 "	
	147 "	
Per cubic yard, $8..		1,176
Lumber used in construction:—		
Mill building, 60 × 110 feet..	155,000 feet.	
Ore bin..	20,000 "	
Belt conveyer house..	6,050 "	
Dryer building, 46 × 70 feet ore shoots and supports..	26,400 "	
Blacksmith and carpenter shop..	7,250 "	
300 ft. dump bridge..	31,000 "	
Divers sheds, etc..	25,000 "	
	271,600 "	
$35 per 1,000 feet, erected..		9,506
Building supplies, hardware, etc., sashes..		775
Machinery and apparatus:—		
1 Jenckes Farrel rock crusher (No. 11B), size 30″ × 15″ fitted with chilled iron jaw plates..		2,242
2 dryer shells, 30″ diameter × 35″ long, complete with all iron-work grates and one smokestack for each dryer..		1,000
1 small single strand 12″ × 6″ bucket elevator, 15 ft. centres.. ..		125
1 revolving rock sizing trommel, special 42″ diameter × 8 feet long, steel shell with 1″ perforation..		350
2 Gates gyratories, at $1,100..		2,200
1 belt conveyer, 18″ wide, 110 ft. centres to mill hopper.. ..		590
2 Butterworth and Low crackers at $715..		1 430
2 fiberizers, 30″ diameter × 6 feet long, at $550..		1,100
2 cyclones, at $600..		1,200
1 sandbelt conveyer, 18″ × 36 ft. centres, complete..		220
2 revolving grading screens, 32″ diameter × 12 feet long, perforated with ⅝″ round holes, made of steel plate, gauge No. 18..		500

1 small type, double strand, perfect discharge bucket elevator, 34 ft. centres, from gyratory to cracker..	460
2 belt conveyers, 10 and 15 ft. centres..	176
2 100 horse-power, 2,200 volt, 3 phase, 3,600 alts., 6 pole, 6,000 R. P.M., C.C.L. induction motors, complete with slide rails, pulley, and starting panel to contain circuit breaker with overload and no-voltage release.	
1 150 horse-power, 2,200 volt, 3 phase, 3,600 alts., 6 pole, 600 R.P.M., C.C.L. induction motor, complete with slide rails, pulley and starting panel to contain circuit breaker with overload and no-voltage release.	
1 10 horse-power, 2,200 volt, 3 phase, 3,600 alts. motor.	
1 50 horse-power, 2,200 volt, 3 phase, 3,600 alts., 4 pole, 900 R.P.M., C.C.L. induction motor, complete with slide rails, pulley and starting device.	
2 5 kw. transformers, 2,000/200 volt primary, 210/120 volt secondary for use with the above 10 horse-power motor, complete with fuse blocks, hanger irons, and oil.	
Total cost of motors..	7,500
Shafts, pulleys, journals, hangers, bolts, sieves, screens, and divers apparatus: fans, collectors, etc., total..	6,750
Installation of machinery and apparatus: including superintendence	8,445
Cartage, freight, and unforeseen expenses..	5,340
Total mill equipment..	$ 51,685

Mine Equipment.

For the beginning of operations, from three to four cable hoists will be sufficient, as a general rule, to supply a mill of the above description with all material needed; for which purpose, additional machinery: compressor, cable derricks, air drills, etc., must be installed. The following figures represent a fair estimate of the cost of the entire equipment:—

2 sets of cable machinery, each set consisting of one 50 horse-power cable hoist, and one 50 horse-power Westinghouse motor: 600 revolutions, variable speed, 3 phase, 6 pole, 2,450 alt., at $2,225	4,450
2 cable derricks, complete with all accessories, at $500..	1,000
2 sheds for hoists..	90
Leveling for tracks, construction of bridges, tracks and sleepers all over property..	565
Machine, carpenter and blacksmith shop, apparatus and tools, total..	2,250
1 10 h.p. motor..	450
2 teams of horses, wagon, harness, blankets, etc., at $600..	1,200
Miners tools, steel shovels, picks..	400
2 air drills, and tripods, at $242..	484
Hose, and other pipes..	300
10 dumping cars, etc..	250
7 drill air compressors..	2,680
1 air receiver..	150
1 125 h.p. motor..	2,500
Freight, cartage, installation of compressors and motor, shed for same..	725
Other expenses not specified..	1,850
Total mine equipment..	$ 19,344



Mill building of the Frontenac Asbestos Mining Co. during construction. (Note the arrangement of beams and the method of bracing. Designer, H. N. Riehie, M.E.

In addition to the above expenditure for mill and mine equipment, a certain sum is required as working capital until the establishment is on a self-sustaining basis. This depends, of course, on the accessibility of the deposits; since those located on a slope above the mill can be mined for about half the cost of those won on shallow ground If we add to the above-mentioned sum, therefore, say $15,000 as working capital, we have the following figures:—

Mill equipment..	$ 51,685
Mine equipment..	19,344
Working capital..	15,000
Total capital required..	$ 86,029

(Exclusive of purchase price of property).

Some of the milling and mining plants of the same capacity have cost a great deal more than the figures cited above. One case is known where a four cyclone mill with mine equipment cost nearly $175,000. Another six cyclone mill recently built, cost over $200,000.

CHAPTER V.

COST OF EXTRACTION, MARKET, PRICES, STATISTICS, AND STATUS OF THE INDUSTRY.

Cost of Extraction.

In the operation of asbestos quarries and mills the cost of mining and milling is obviously a matter of great importance. A number of important factors enter into it:—

(1) The quantity of ore treated.

(2) Cost of labour.

(3) The quality of the ground in which the quarry is being worked.

Owing to the variation of the latter, the total cost will vary in different mines, hence any generalization as to the comparative cost of quarrying and treatment, per ton of asbestos, would be futile; being matters entirely dependent upon the quality of the rock, the percentage of fibre contained therein, and the kind of plant employed.

In the first edition of this monograph one example of costs was given, in which a quarry was operated under supposed normal conditions; but it must be admitted that the term 'normal' is not well applied to asbestos mining; since the conditions of two quarries may be entirely different, yet the ultimate financial results, that is the profits, might be the same, or nearly so. For this, and other reasons, therefore, no detailed statement of expenses of any one quarry is submitted; simply a statement of reliable, eclectic, general facts:—

In the Broughton district, where almost all the rock passes through the mill, and no 'crude' is produced, the cost of production of one ton of fibre—based on an 8 per cent extraction—may be put at from $12.50 to $14 a ton: including all expenses caused by mill repairs—administration expenses are not included in this item.

In the Thetford and Black Lake quarries, where the production of 'crude' enters into the mine costs, the average cost of extraction—crude and mill fibre combined—may be placed at from $20 to $27 per ton, exclusive of expenses for management, offices, insurance, marketing, amortization, etc.

Market and Prices.

The chief markets for Canadian asbestos are the United States, England, Germany, and France, and to a lesser degree, Russia, and Italy. Most of the mill fibre and paper stock is sold at present in the United States; while large quantities of 'crude' are consumed by the European countries. That the general excellence of the Canadian mineral is now universally acknowledged, is evidenced by the fact that, most of the civilized countries—keeping pace with the development of new applications—import asbestos in large quantities; and every

year witnesses a considerable increase in the exports of this mineral. Canada thus dominates the asbestos markets of the world.

A previous writer on the subject ventured to predict that other countries, where mining was carried on somewhat extensively some six or eight years ago, would, in time, successfully compete with the Quebec quarries, and that the monopoly thus far held by Canada would be weakened and even destroyed; and that, as a consequence, the prices would drop to a lower figure. But nothing of the kind has happened; and although new discoveries of asbestos are frequently reported, they have invariably proved to be either unimportant in extent, or of unsuitable quality; and thus the profitable extraction of large quantities of asbestos is still confined to Canada.

A glance at the statistics of the world's productions for 1908 will show that Canada delivered 82·6 per cent of the total supply, and there is every reason to believe that the Dominion will continue to maintain this monopoly for some time to come: an inevitable conclusion after reviewing the existing condition of the asbestos industries in all parts of the globe.

It must be admitted that Russia increases its output every year, but the facts must not be lost sight of, (1) that in that part of the asbestos region the ground is swampy, shallow, and not drained, hence the pits fill rapidly with water; (2) that the ground is heavily covered with forest and overburden; and (3) that the working season lasts only from May to October. Moreover, the transportation charges of Russian asbestos to the seaboard amount to $25 or $30 per ton, and consequently, only competition in the higher grades may be feared; but not in the Canadian mill product, which sells at from $25 to $50 per ton.

Another important fact bearing on this question of commercial supremacy is, that for reasons of their own, the German and Austrian manufacturers buy the Canadian 'crude' in preference to the Russian; although the latter is cheaper,

The heaviest buyer of the Canadian mill fibre is the United States. According to the reports of the United States' Geological Survey in 1908, over half of the Canadian production went to that country.

The writer has gleaned from interviews with men who have made the commercial aspect of asbestos their life-long study, that the Canadian asbestos industry has nothing serious to fear from competition on the part of foreign countries; owing to the superior quality of the Canadian product. Judging from the many samples sent in from all parts of the world, for examination, the writer ventures the opinion that, no asbestos hitherto discovered, combines such silkiness and length as that found in Thetford.

As evidence of faith in the future of the Canadian asbestos industry, it may be mentioned that not only are new quarries being constantly opened, and milling plants being erected at the present time; but some of the older establishments are actually acquiring additional asbestos ground, and increasing considerably their output by the erection of new mills of large capacity, details of which will be found in the chapter dealing with the working quarries. In spite of the periodical slump in prices—due to causes attributable, for the most part, to the

financial manipulations of buyers in the consuming countries—it is a fact that prices for all grades have advanced about 40 per cent during the past five years. A table showing the price conditions over a period of fourteen years will illustrate this, without further comment.

The prices paid at present, per ton of 2,000 pounds, are as follows:—

No. I crude asbestos	$275
No. II crude asbestos	160
No. I mill fibre	100 to $110
Run of mine mill fibre	45 to 50
No. II mill fibre	22 to 45
No. III mill fibre	10 to 14

The shipping points for Europe are Montreal, during the navigation season; and St. John, N. B., during the winter. The freight rates are regulated by the quality of the goods shipped and also by their volume per short ton. They were for 1909-10 as follows:—

Thetford Mines to London:—

Crude asbestos, measurement 40 cubic feet,
through rate 30·71 cents per 100 pounds—
of which, 20 cents represents inland, and 10·71 cents, ocean freight.

Asbestos fibre, measurement 70 cubic feet,
through rate 28·40 cents per 100 pounds—
of which, 15 cents represents inland and 13·40 cents, ocean freight.

Asbestos fibre, measurement 90 cubic feet,
through rate 31·07 cents per 100 pounds—
of which, 15 cents represents inland, and 16·07 cents, ocean freight.

The port of Quebec has, hitherto, been in disfavour as a shipping point; for the reason that the goods have to be transhipped by wagon and ferryboat from Levis—the westward railway terminus to the Quebec side—necessitating an extra outlay of 4½ cents per 100 pounds.

Statistics.

The following tables of production and values since the year 1880 are computed from the returns of the Geological Survey 'Section of Mines'; and subsequently from the statistical returns published by the Mines Branch of the Department of Mines, Ottawa; and also from the publications of the Quebec Bureau of Mines.

PRODUCTION OF ASBESTOS IN CANADA. 1880-1895.

Calendar Year.	Tons (2,000 lbs.)	Value.	Average value per ton.
		$	$ cts.
1880	380	24,700	65 00
1881	540	35,100	65 00
1882	810	52,650	65 00
1883	955	68,750	71 99
1884	1,141	75,097	65 82
1885	2,440	142,441	58 38
1886	3,458	206,251	59 64
1887	4,619	226,976	48 92
1888	4,404	255,007	57 90
1889	6,113	426,554	69 78
1890	9,860	1,260,240	127 81
1891	9,279	999,878	107 76
1892	6,082	390,462	64 20
1893	6,331	310,156	86 81
1894	7,630	420,825	55 15
1895	8,756	368,175	42 05

PRODUCTION OF ASBESTOS AND ASBESTIC IN CANADA, 1896-1909.

Calendar Year.	Tons (2,000 lbs.)	Value.	Asbestos. Average value per ton.	Asbestic. Average value per ton.
		$	$ cts.	$ cts.
1896—Asbestos	10,892	423,066	38 84	
—Asbestic	1,358	6,790		5 00
1897—Asbestos	13,202	399,528	29 99	
—Asbestic	17,240	45,840		2 66
1898—Asbestos	16,124	475,131	29 47	
—Asbestic	7,661	16,066		2 10
1899—Asbestos	17,790	468,635	26 34	
—Asbestic	7,746	17,214		2 22
1900—Asbestos	21,621	729,886	33 76	
—Asbestic	7,520	18,545		2 47
1901—Asbestos	32,892	1,248,645	37 96	
—Asbestic	7,325	11,114		1 52
1902—Asbestos	30,219	1,126,688	37 28	
—Asbestic	10,197	21,631		2 20
1903—Asbestos	31,129	915,888	29 42	
—Asbestic	10,548	13,869		1 31
1904—Asbestos	35,068	1,154,566	34 08	
—Asbestic	13,087	13,006		1 00
1905—Asbestos	50,670	1,486,359	29 33	
—Asbestic	17,594	16,900		0 96
1906—Asbestos	59,283	1,970,878	33 52	
—Asbestic	20,127	17,230		1 11
1907—Asbestos	62,018	2,482,984	39 99	
—Asbestic	28,519	22,059		0 72
1908—Asbestos	66,548	2,555,361	38 40	
—Asbestic	24,225	17,974		0 74
1909—Asbestos	63,349	2,284,587	36 07	
—Asbestic	23,951	17,186		0 72

STATISTICAL RETURNS FOR 1901-9: AS PUBLISHED BY THE DEPARTMENT OF LANDS AND MINES, PROVINCE OF QUEBEC.

—	1901.		1902.	
	Tons.	Value.	Tons.	Value.
		$		$
Crude No. I	2,083	348,579	1,319	240,401
Crude No. II	2,660	263,855	3,131	305,312
Fibre	14,659	450,193	15,502	412,388
Paper stock	14,054	211,688	10,682	203,869
	33,456	1,274,315	30,634	1,161,970
Asbestic	6,831	10,114	9,764	12,783

—	1903.		1904.	
	Tons.	Value.	Tons.	Value.
		$		$
Crude No. I	930	117,847	1,645	251,818
Crude No. II	2,354	227,919	2,727	265,961
Fibre	9,650	311,248	7,771	229,801
Paper stock	16,327	259,956	23,336	439,215
	29,261	916,970	35,479	1,186,795
Asbestic	9,906	13,292	13,149	13,124

—	1905.		1906.	
	Tons.	Value.	Tons.	Value.
		$		$
Crude No. I	1,340	221,325	1,477	324,380
Crude No. II	2,258	243,785	2,450	321,355
Fibre	10,707	386,440	18,542	815,962
Paper stock	34,655	624,900	39,906	681,956
	48,960	1,476,450	62,375	2,143,653
Asbestic	1,920	31,100	21,119	18,875

	1907.		1908.		1909.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
		$		$		$
Crude No. I	1,487	367,438	900	261,216	912	246,655
Crude No. II	2,938	462,323	2,771	438,305	2,162	328,855
Fibre	19,905	780,013	13,911	716,811	14,776	785,731
Paper stock	37,655	846,145	47,574	1,135,264	45,499	923,346
	61,985	2,455,919	65,157	2,551,596	63,349	2,284,587
Asbestic	29,193	27,292	24,011	17,970	23,951	17,188

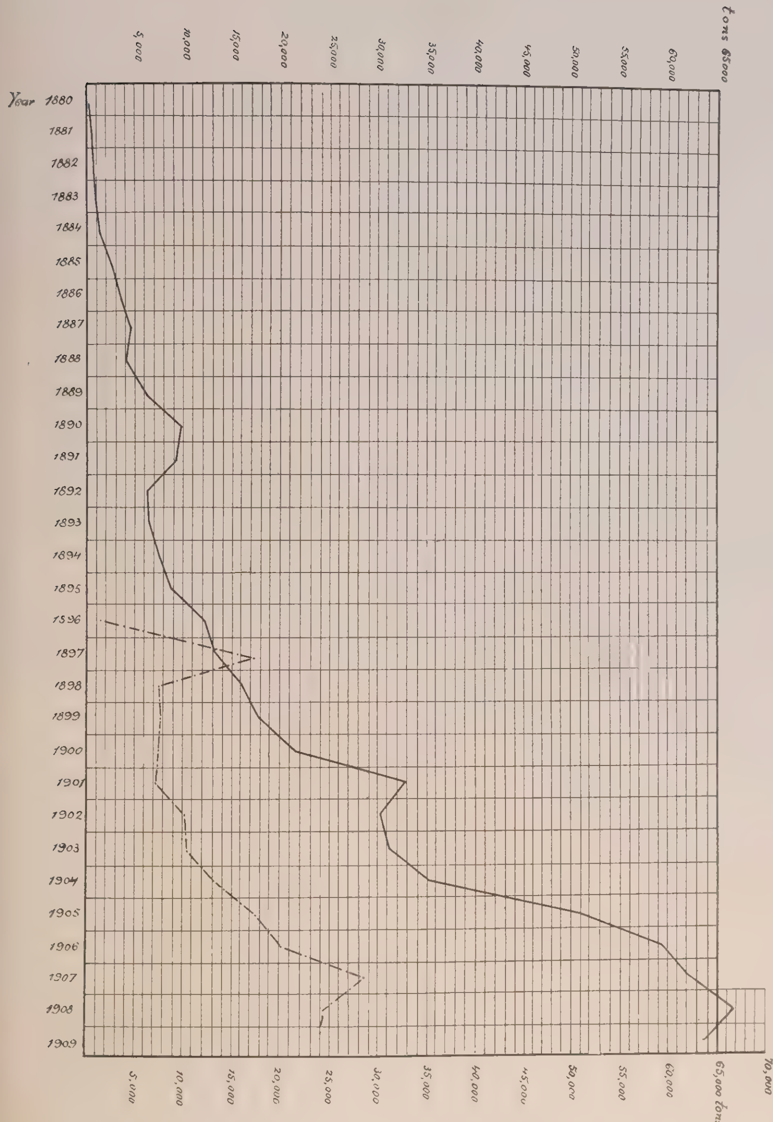


FIG. 48.—Production of Asbestos and Asbestic, 1880-1909.

According to the foregoing statistics, the total production of the quarries for the period from 1901 to 1909, inclusive, was composed of:—

35,544 tons of crude,

125,423 tons of fibre.

269,688 tons of paper stock.

SUMMARY OF PRODUCTION.

Year.	Crude.	Fibre.	Paper Stock
	Tons.	Tons.	Tons.
1901	4,743	14,659	14,054
1902	4,450	15,502	10,682
1903	3,284	9,650	16,327
1904	4,372	7,771	23,336
1905	3,598	10,707	34,665
1906	3,927	18,542	39,906
1907	4,425	19,905	37,655
1908	3,671	13,911	47,574
1909	3,074	14,776	45,499
Total.	35,544	125,423	269,688

ANNUAL PRODUCTION OF CRUDE AND MILL STOCK, 1903–1909.

Calendar Year.	Crude.			Mill Stock.		
	Short Tons.	Value.	Per ton.	Short Tons.	Value.	Per ton.
		$	$ cts.		$	$ cts.
1903	3,134	361,867	115 46	27,995	554,021	19 79
1904	4,410	534,874	121 28	31,201	678,628	21 75
1905	3,767	472,859	125 53	46,902	1,013,500	21 61
1906	3,841	635,345	165 41	56,920	1,401,083	24 61
1907	4,427	830,632	191 97	57,803	1,654,135	28 62
1908	3,345½	669,232	200 04	63,202	1,886,129	29 84
1909	3,074	575,510	187 22	60,275	1,709,077	28 35

ANNUAL EXPORTS—CALENDAR YEARS, 1892-1908.

Calendar Year.	Tons.	Value.	Value per ton.	Calendar Year.	Tons.	Value.	Value per ton.
		$	$ cts.			$	$ cts.
1892	5,380	373,103	69 35	1901	32,269	1,069,918	33 16
1893	5,917	338,707	57 24	1902	31,074	995,071	32 02
1894	7,987	477,837	59 82	1903	31,780	891,033	28 04
1895	7,442	421,690	56 66	1904	37,272	1,160,887	31 14
1896	11,842	567,967	47 96	1905	47,031	1,386,115	29 47
1897	15,570	473,274	30 40	1906	59,854	1,689,257	28 22
1898	15,346	494,012	32 19	1907	56,753	1,669,299	29 41
1899	17,[illegible]83	473,148	26 46	1908	61,210	1,842,763	30 11
1900	16,993	693,105	39 61				

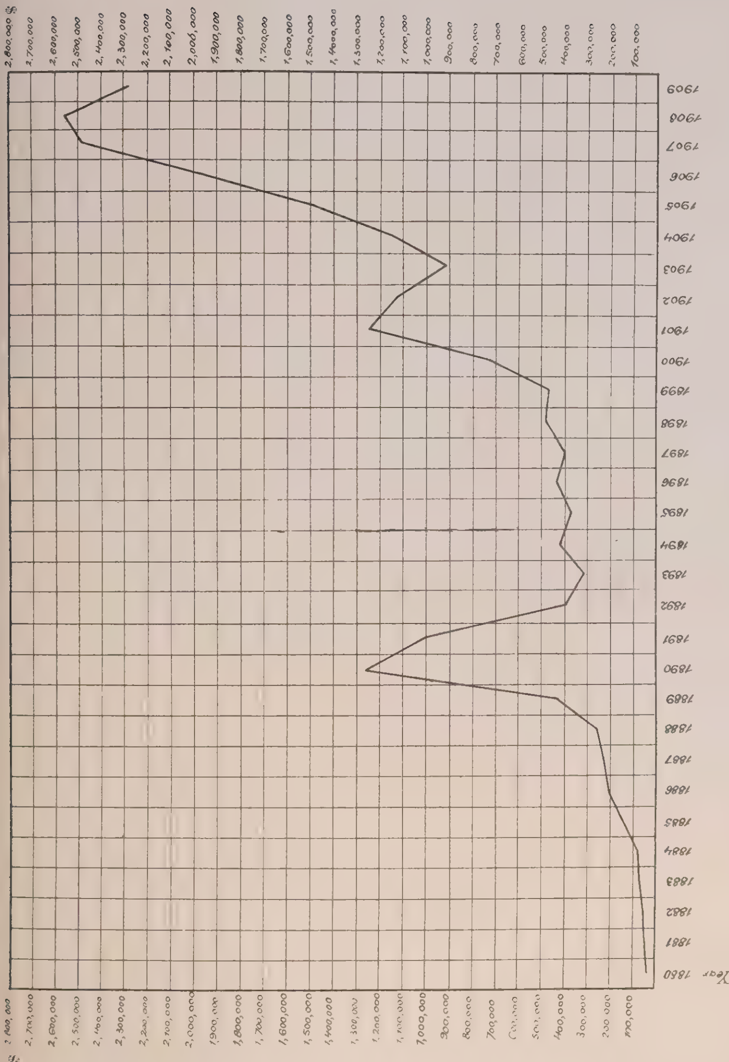


FIG. 49.—Value of production of Asbestos and Asbestic, 1880-1909.

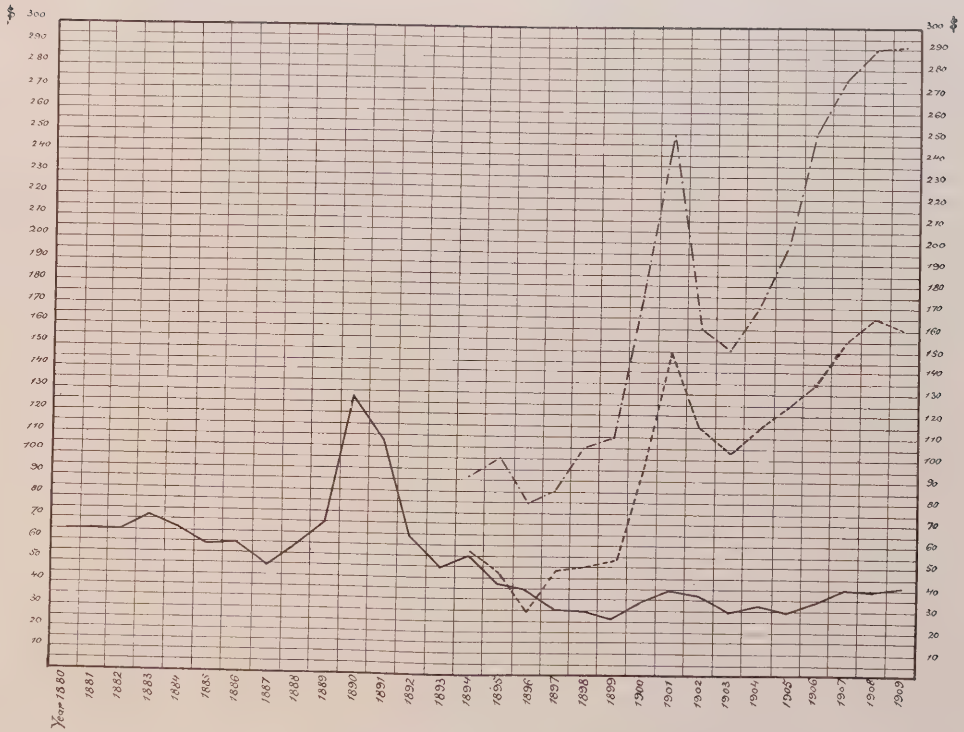


FIG. 50.—Average prices of Asbestos and Asbestic, 1880-1909.

— · — · — · — First quality of crude.

— — — — — Second quality of crude.

———————— Average price of all grades, crude and mill fibre.

EXPORTS OF ASBESTOS FROM CANADA.[1]

Statement showing the amount of Asbestos exported from Canada during the years ending June 30, 1895 to 1910.

Year ending June 30.	Great Britain.	Australasia.	Belgium.	British Africa.	France.	Germany.	Holland.	Italy.	Newfoundland.	Russia.	St. Pierre.	United States.	Austria-Hungary.	Japan.	Norway.	Totals.
							QUANTITIES.									
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1895	2,202	....	12	....	....	358	28	....	....	....	....	5,993	....	....	....	8,593
1896	1,769	....	205	....	272	1,463	....	....	....	....	....	5,879	....	....	....	9,588
1897	3,388	....	....	....	....	1,157	....	....	....	....	....	6,424	....	....	....	10,969
1898	1,939	....	115	....	....	1,800	....	....	....	....	....	14,570	....	....	....	18,424
1899	1,418	....	237	....	....	377	....	....	....	....	....	12,488	....	....	....	14,520
1900	1,732	....	414	....	....	2,541	....	....	....	....	....	13,477	....	....	....	18,164
1901	3,324	136	2,211	....	240	2,235	206	167	1	....	78	18,117	....	....	....	26,715
1902	4,088	....	827	....	365	2,270	....	469	....	....	....	25,053	....	....	....	33,072
1903	2,813	....	964	26	192	1,119	110	568	2	....	....	24,867	....	....	....	30,661
1904	4,375	1	1,354	121	1,154	1,894	173	560	4	20	....	24,980	....	....	....	34,636
1905	7,132	....	1,135	....	1,375	3,900	80	693	28	....	....	26,784	....	....	....	41,127
1906	8,614	10	2,692	....	1,746	4,344	....	592	1	....	....	38,896	165	....	15	57,075
† 1907	9,129	....	3,098	....	1,192	541	....	175	....	....	....	26,821	20	32	....	41,008
* 1908	5,347	....	3,372	....	2,332	225	....	814	....	....	....	46,846	....	97	....	59,033
* 1909	5,626	....	3,063	....	1,608	381	....	97	....	....	....	48,940	....	17	....	59,732
* 1910	5,550	20	3,117	....	2,339	770	100	377	....	....	....	51,710	55	....	....	64,038

* Year ending March 31. † 9 months.

Year ending June 30.	Great Britain.	Australasia.	Belgium.	British Africa.	France.	Germany.	Holland.	Italy.	Newfoundland.	Russia.	St. Pierre.	United States.	Austria-Hungary.	Japan.	Norway.	Totals.
							VALUES.									
	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
1895	118,852	....	1,110	....	....	27,036	2,800	....	....	....	....	343,277	....	....	....	493,075
1896	96,863	....	15,375	....	12,107	117,918	....	....	....	....	....	240,416	....	....	....	482,679
1897	236,598	....	....	....	....	67,766	....	....	....	....	....	206,552	....	....	....	510,916
1898	94,539	....	7,800	....	....	43,295	....	....	....	....	....	364,734	....	....	....	510,368
1899	66,623	....	13,100	....	....	12,052	....	....	....	....	....	361,401	....	....	....	453,176
1900	70,749	....	16,260	....	....	80,916	....	....	....	....	....	322,984	....	....	....	490,909
1901	136,294	692	161,468	....	25,397	85,345	4,480	2,975	58	....	778	447,086	....	....	....	864,573
1902	201,474	....	41,912	....	30,245	89,868	....	23,940	....	....	....	743,763	....	....	....	1,131,202
1903	98,167	....	22,226	70	19,740	28,646	7,275	21,455	102	....	....	757,724	....	....	....	955,405
1904	116,866	33	13,428	5,000	53,412	47,560	10,200	28,311	245	400	....	709,381	....	....	....	984,836
1905	243,249	....	74,037	....	44,862	135,121	6,400	36,875	2,850	....	....	768,130	....	....	....	1,311,524
1906	262,774	300	87,635	....	49,520	111,617	....	23,993	150	....	....	1,036,648	4,950	....	450	1,578,137
† 1907	292,620	....	96,341	....	32,416	20,065	....	3,751	....	....	....	759,907	600	1,076	....	1,206,776
1908	237,152	....	86,871	....	50,612	8,195	....	21,678	3,177	....	....	1,322,890	....	....	....	1,730,575
1909	233,653	....	159,758	....	57,640	10,055	....	1,379	....	....	....	1,294,977	....	595	....	1,758,057
1910	283,367	300	155,664	....	99,815	22,444	12,580	10,956	....	....	....	1,300,457	1,030	....	....	1,886,613

[1] Department of Trade and Commerce, Ottawa. † 9 months.

Imports of Asbestos Goods.

Canada does not, as yet, manufacture all the asbestos goods required for home consumption. The following table will show the value of goods imported since the year 1885:—

IMPORTS FISCAL YEARS 1885-1910.

Fiscal Year.	Value.	Fiscal Year.	Value.	Fiscal Year.	Value.
	$		$		$
1885	674	1894	20,021	1903	75,465
1886	6,831	1895	26,094	1904	83,827
1887	7,836	1896	23,900	1905	116,836
1888	8,793	1897	19,032	1906	137,974
1889	9,943	1898	26,389	1907 (9 months)	127,509
1890	13,250	1899	32,607	1908	190,980
1891	13,298	1900	43,455	1909	181,710
1892	14,090	1901	50,829	1910	198,756
1893	19,181	1902	52,464		

Status of the Industry.

Since the publication of the first edition of my Monograph on Asbestos, in 1904, the industry has experienced great expansion.

Owing to fresh discoveries, new, productive ground has been added—especially in the Broughton and Thetford districts; while asbestos deposits located some twenty years ago, when mechanical separation was unknown, have been developed, and put on a productive basis.

Four new quarries and mills have thus been added to the list of producers, and the mining and milling capacities of almost all the quarries which were working in 1904 have been considerably increased: in two cases, even doubled.

STATUS OF THE INDUSTRY IN THE YEARS 1896, 1904, AND 1909.

Year.	Producing Companies.	Authorized Capitalization of Producing Companies.	Mines in Operation.	Mills in Operation.	Number of Cyclones or their equivalent installed.	Mill Capacities (120 tons per day per Cyclone.)	Horse-power Used.		Total Horse-power	Persons Employed.	Wages Paid.
							Steam.	Electric.			
		$				Tons.					$
1896..........	....	....	....	6	....	900	....	....	1,500	500	125,000
1904..........	10 (a)	....	10 (c)	16 (d)	30	3,600	....	....	4,200	1,775	460,300
1909..........	10 (b)	24,290,000	15	19 (e)	71	8,520	3,960	8,040	12,000	3,008	1,349,864

(a) Most of these companies were close corporations.
(b) A number of the older companies were consolidated into one large corporation.
(c) Three mines have suspended operations since 1908.
(d) Two of these mills have been dismantled, and two others which have not been in operation since 1907 have been partly dismantled.
(e) Contains only mills which were producing in 1909.

WORLD'S PRODUCTION OF ASBESTOS SINCE 1902 IN GROSS (METRIC) TONS.

—	1902.	1903.	1904.	1905.	1906.	1907.	1908.
Canada	27,414	28,240	32,306	45,967	55,122	56,364	60,372
United States	912	805	1,343	2,820	1,538	592	849
Russia : Ural	4,507	5,624	7,502	5,776	9,201	9,500	10,540
Siberia (Yenesei)	.....	.....	.....	1,490	.....	.....	.....
Cape Colony	41	276	373	454	473	548	770
Cyprus	.....	.....	.....	.....	19	89	330
Western Australia	.....	.....	.....	.....	.....	.....	40
Transvaal	.....	.....	.....	.....	.....	.....	25
Rhodesia	.....	.....	.....	.....	.....	.....	120
	32,874	34,945	41,524	56,507	66,353	67,093	73,046

INCREASE IN PRODUCTION, CAPACITIES OF MILLS; CANADA'S SHARE IN WORLD'S PRODUCTION.

Year.	Production in Canada.	Value.	Canadian Production, Increase.	Capacities of all Mills.	Mill Capacities, Increase.	Total World Production.	World Production, Increase.	Percentage of Canada in World's Production.
	Metric tons.	$	Per cent.	Tons.	Per cent.	Metric tons.	Per cent.	Per cent
1902	27,414	1,161,970	....	2,500	....	32,874	....	83·4
1904	32,306	1,186,795	(1902–4) 17·8	3,500	(1902–4) 40·0	41,524	(1902–4) 26·3	77·8
1908	60,372	2,551,596	(1904–8) 86·8	8,250	(1904–8) 135·7	73,046	(1904–8) 75·9	82·6

The following table shows the increase in the production of mill fibre, and the gradual increase in prices for 'crude' as well as 'mill stock':—

Year.	Crude.			Mill Stock.		
	Tons.	Value.	Per ton.	Tons.	Value.	Per ton.
		$	$ cts.		$	$ cts.
1903	3,284	345,766	105 29	25,977	571,204	21 98
1904	4,372	517,779	118 43	31,107	669,016	21 50
1905	3,598	465,110	129 26	45,362	1,011,340	22 29
1906	3,927	645,735	164 43	58,448	1,497,918	25 62
1907	4,425	829,761	187 51	57,560	1,626,158	28 73
1908	3,671	699,521	190 55	61,485	1,852,075	30 12
1909	3,074	575,510	187 22	60,275	1,709,077	28 35

The above table shows a gradual increase in the total production; but this increase is confined exclusively to the mill fibre. The production of crude is, to-day, about the same as it was eight years ago; but its value per ton has nearly doubled. The remarkable feature is, the increase in the value of the production of the mill fibre over that of the 'crude'; whereas five years ago the total value of the mill stock was only $200,000 more than that of crude: it now exceeds the crude by $1,200,000.

Five mills are under construction at present, containing twenty-six cyclones. These establishments are to be in operation by the spring of 1910. An output of 120 tons per cyclone per day, will mean an additional increase in capacity of 3,120 tons of rock; and assuming an extraction of 5 per cent the total production of asbestos per day will be 156 tons.

It must be mentioned, however, that the above figures indicate the maximum capacity of all the mills in the district; and that in practice their maximum output is never attained, owing (1) to the fact that in all the newer mills a number of cyclones are installed for emergency purposes only, hence, are not all the time in actual use; (2) that some mines work on poorer ground than others, which often necessitates a curtailment of operations, and sometimes temporary suspension; and (3) that the demand for the material is subject to caprice. Again, operations during the severe winter seasons in some mines are suspended, while in others they are actually curtailed.

New applications and uses for the material are discovered continually; especially since the paper stock or the short fibre has been put on the market—through improved methods of separation. A product which absorbs at the present time large quantities of the medium grade mill fibre is 'asbestos slate'; and it is principally the enormous absorption of mill fibre in the manufacture of the article specified, that has caused such a phenomenal expansion in the asbestos industry of late. This 'asbestos slate' is, to-day, the most important article on the list of manufactured asbestos goods; and as in the past, so in the immediate future, it is likely to become increasingly in demand.

The asbestos industry, as a whole, has taken an altogether different aspect since the introduction, some fourteen years ago, of mechanical separation, which has enabled the operator to extract the small fibre from the rock. Quarries which cannot produce the high grade of 'crude' qualities, have a chance to realize on the abundant quantities of small fibre stored in the mill rock; while in the case of the larger and richer mines, additional profits can be made.

It is, of course, possible, that if all the new mines and mills put their product on the market simultaneously, over production and a consequent drop in prices may follow. However, the ever increasing consumption of asbestos in the manufacture of slate, as well as the constant discovery of new uses, augur well for a continually increasing demand; in spite of temporary lulls such as we witness in other line of business; hence for this reason, no serious results need be anticipated.

Again, the transportation facilities are so great, that it may be stated here, that no mining camp on the North American continent can compare in that respect with the Canadian asbestos quarries. It so happens that the productive belt follows closely the sinuosities and winding course of the railway, which by the way, was established before the asbestos mines were discovered. There is, at the present time, no working quarry farther than 1½ miles from the railway line.

And now one word with regard to the future of the Canadian supply. The economic question is of great importance, and has already occupied the attention of those who like to speculate on the extent of the resources. After an extensive investigation all over the Quebec asbestos field for several seasons past, the writer has come to the conclusion that, the available productive area compared with the whole serpentine belt is indeed small. Exploration work carried on over a number of years all over the serpentine belt has failed to add materially to the already productive area. It is true, quite a number of discoveries have been made in the Eastman and Richmond districts; but their commercial value has not been established in any one instance. However, six new, and promising discoveries have been made in the Black Lake, Thetford, and Broughton districts during the past five years. On some of those deposits, milling plants are now being erected; while others are under development, with a view to their exploitation. Several new mills are being placed on ground which has been known for over twenty years; having been operated at a time when mechanical appliances had not been generally introduced. All these large mills now under construction will, when fully operated, increase the production about 33 per cent; while the newly discovered deposits, as well as the very large ore reserves on the mines in active operation, will take care of any further demand—through increased consumption—for many, many, years to come. As an example of the extent of some of these ore reserves, the writer, from personal investigation and surveys, is able to state that, in one of the quarries in Black Lake there are 44,377,500 tons of asbestos rock in sight above the railway track, ready for immediate exploitation. Deducting 50 per cent from this for waste rock, it means that there are in sight 22,000,000 tons of asbestos mill rock; a quantity sufficient to keep a milling plant with a daily capacity of 4,000 tons running for almost twenty-two years—less 200,000 tons per annum deducted on account of the severe winter season.

Much speculation is being manifested at the present time, with regard to the depth of the asbestos deposits. Excepting in the case of one of the chrome iron ore mines, where asbestos was encountered at a depth of 400 feet, there is no tangible evidence, in any operating asbestos mine, of the presence of asbestos below a depth of 200 feet—the lowest level so far attained in one of the older quarries. However, from a geologic point of view, there is some ground for the belief that, asbestos deposits are deep-seated: in other words, that asbestos may yet be found at considerable depth. Further particulars in connexion with this subject will be found on pages 94-102.

Beaver quarry of the Amalgamated Asbestos Corporation, Thetford, Que.

CHAPTER VI.

ASBESTOS MINES AND PROSPECTS.

Amalgamated Asbestos Corporation, Limited.

Locality.—Thetford and Black Lake, Que.

President.—Thos. MacDougall, Esq., Montreal.

Secretary Treasurer.—R. P. Doucet, Montreal.

General Manager.—R. H. Martin, New York.

Consulting Engineer.—Earle C. Bacon, New York.

Mining Engineer.—Fritz Cirkel, Montreal.

Head Office.—163 St. James Street, Montreal.

Incorporated.—Under the laws of the Dominion of Canada, 1909.

Authorized Capital.—

Bonds authorized	$ 15,000,000	
Reserved for future requirements	7,500,000	
Issued		$ 7,500,000
Stock: 7 per cent cumulative preference shares, par value $100		1,875,000
Common stock: par value $100		8,125,000
		$ 17,500,000

Mining lands held.—8,091 acres in the Thetford and Black Lake asbestos areas.

Number of men employed.—1,525; in busy season about 2,000.

This Corporation bought, in the beginning of 1909, all the assets and stock in trade, etc., of the mines then working under the following names: King Asbestos Mines, and Beaver Asbestos Company, at Thetford; and the British Canadian Asbestos Company, Limited, Dominion Asbestos Company, Limited, and Standard Asbestos Company, Limited, at Black Lake.

The Company have plans laid out that will enable them to greatly increase, in the near future, the output of the properties acquired. The plants of the bigger properties like the King and the British Canadian, are being thoroughly overhauled; the milling plant of the Beaver is being enlarged to such an extent that the production will be increased from 375 tons to 700 tons of asbestos per month; at the Standard new crushers and more modern machinery have been put in, permitting an output of 500 tons per month, instead of 250 tons as heretofore. The Dominion, which had scarcely been worked in former years, has, since its acquisition by this Corporation, made many improvements, and it is expected that this property will have an average output of from 550 to 600 tons per month.

The mills and quarries are connected by five miles of railway, vested in the private ownership of the Corporation, which is worked by 8 locomotives, 250 cars, and the necessary associated equipment.

With a view to securing a larger amount of labour, and looking after the welfare of the employes in a more effective manner, the Company intends erecting large boarding houses, both at Black Lake and at the Thetford quarries.

With the completion of all these improvements, this Corporation will be in a position to increase its output fully 25 per cent, in the year 1910, and thus keep pace with the great demand for its products. In this connexion it may be stated that, this Company, at the end of the year 1909, had over $3,000,000 worth of unfilled orders on hand.

A description of all the quarries and milling plants is given in the following pages:—

THE BEAVER QUARRIES.

Locality.—Thetford, Que.

Manager.—A. E. Martin.

Mining lands.—500 acres, comprising lots 31 and 32, range C, Coleraine, and lot 36, range XI, Ireland.

Number of men employed.—Average, 175.

These quarries were formerly worked by the Beaver Asbestos Company—one of the oldest concerns working in this district. Operations were from time to time suspended, depending upon market conditions; but the milling plant, some years ago, was kept very busy working over rich dumps which had accumulated from the early operations. For several years past the quarry and mill have been kept in operation. Additional good asbestos ground was discovered last year. The principal pit is centrally located, not far from the Quebec Central Railway track; and the milling plant immediately adjoins the latter. This main pit measures about 700 × 250 feet, by 80 feet deep: its main axis having a strike northwest 40°. Seven cable derricks, of the tail rope type, are placed in one row on the westerly side of the big pit. The No. 2 pit measures about 40 × 50 feet by 40 feet deep, and is located close to the northwesterly end of the latter, with which it will be connected in the near future. Six machine drills, actuated by compressed air, are in commission. The hoists for the cable derricks—7 in number, are placed in one central power house; they are all run by steam generated in one of the big boilers of the power house.

The mill is driven by a 300 horse-power electric motor, and has a capacity of 400 tons in two shifts. The equipment consists of 1 Campbell dryer placed in a separate building, jaw crusher, rotary crusher, 3 cyclones, and all accessories. The milling ore is received in a skip from a hopper, into which the ore coming from the mine is dumped. This skip is hoisted to the top of the mill and the ore delivered thence to the crushers. The power house is attached to the mill, and contains an auxiliary plant consisting of 5 boilers: three of which have a capacity of 100 horse-power each, and two of 150 horse-power each; or a total of 600 horse-power. This whole plant can be put in operation at two hours

notice. One 14 drill air compressor driven by a 100 horse-power motor, and placed in the same building, furnishes air for the drills.[1]

The main track of the Quebec Central railway, with a siding, runs alongside the large store shed, and offers great facilities for handling the output and the sand. The sand is delivered automatically by means of a chain scraper direct into the railway cars. A machine repair and carpenter shop located close to the mill make up the balance of the plant. The Company have built on the south side of the track, 35 dwellings, and leased them to their workingmen. There is also a beautiful villa for the manager, with the superintendent's house on the premises.

THE BRITISH CANADIAN QUARRIES.

Locality.—Black Lake, Que.

Manager.—B. Bennet.

Number of men employed.—Full working force, 600.

These quarries were formerly operated by the British Canadian Asbestos Company; who took over in the beginning of 1908 all the assets of the American Asbestos Company. When this Company commenced operations in 1903, the task before them was very difficult; the properties had only been partially tested: there was no mining equipment; no mill on the premises. In less than a year, however, the Company had two pits fully equipped and in operation, while a new mill substantially constructed; and of large capacity, handled the output, which on some days attained 500 tons of asbestos rock, or two carloads of asbestos. The Company, realizing the expanse of the applications of asbestos and the consequent demand upon the asbestos industry, gradually acquired additional property; and in 1907 consummated a deal whereby the properties of the Glasgow and Montreal; the United; and the Manhattan, were absorbed. This involved the acquisition of 200 acres of valuable ground; and led to a considerable increase in the production of 'crude' asbestos; hence, although formerly the mill had all it could do to handle the milling material from the various pits, the additional 'crude' coming from the new pits provided an asset which enhanced the value of the undertaking in a considerable measure.

The works may be divided into three sections: (1) the upper—comprising the old pits of the newly acquired ground of the Glasgow and Montreal, and the Manhattan; (2) the centre—containing all the pits formerly worked by the American Asbestos Company; and (3) the lower—comprising all the refining works, repair shops, and accessory buildings close to the Quebec Central Railway track.

In the upper section, the highest pit on the mountain slope is located on the old Glasgow and Montreal ground, and measures 100 × 130 feet and 60 feet deep. The other three pits of the upper section are located just below the one above referred to, and vary in size from 75 × 100 feet to 125 × 200 feet, and the depth from 50 to 90 feet. One power house erected in a central spot supplies all the steam used for 4 hoists and cable derricks, 2 boom derricks, 3 steam drills, and 2 duplex pumps; and consists of two boilers, each of 50 horse-power capacity

[1] Since writing the above the whole plant of the Beaver has been overhauled and changed, and its capacity increased to 600 tons per day.

Four cobbing sheds located at convenient places receive all the crude. The mill material from the pits, and all waste from the cobbing sheds are transported by means of a 5 ton self dumping steel skip, down a tramway—1,600 feet long, operated by a 60 horse-power Bacon hoist—to a hopper, from whence they are loaded into 4 ton dumping cars and carried down to the large mill.

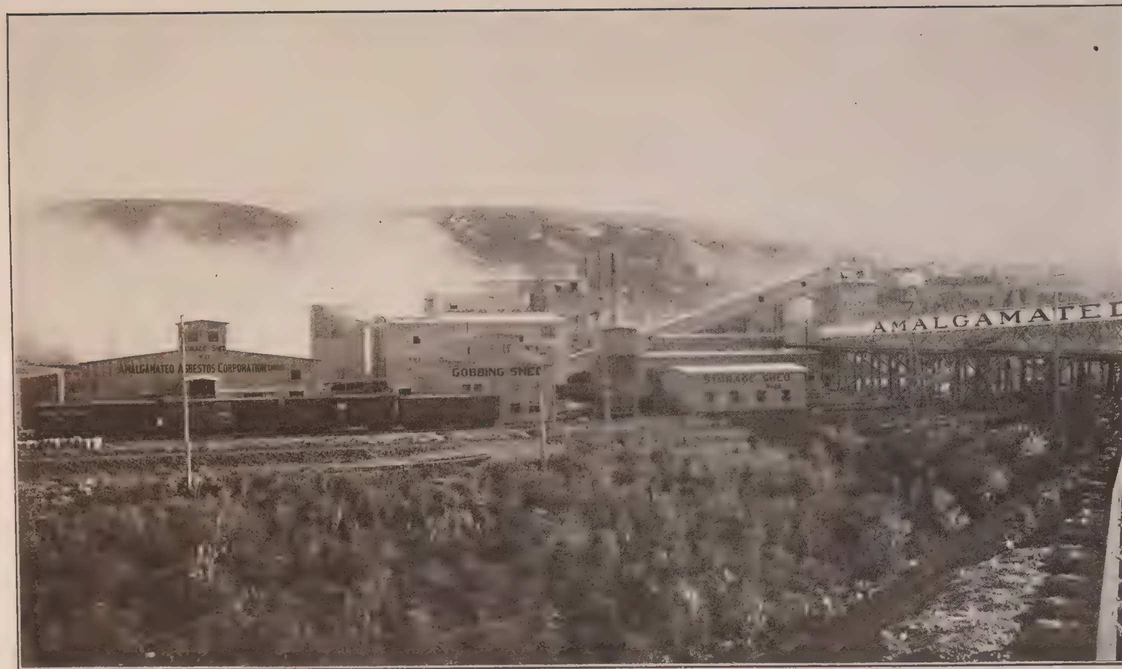
The middle section comprises two large pits: the more easterly one measuring about 200 × 150 feet, and 100 feet deep; and the other one—the largest pit on the property—400 × 200 feet, and 50 feet deep. The easterly pit is served by 2 cable derricks of the tail rope type, operated by 2 electric hoists, and 2 boilers of 35 horse-power; each of which supplies steam to pumps and drills.

The big pit is operated by 4 cable derricks, 1 boom derrick, 2 drills, and 5 hoists; the latter being supplied with steam from a central power station having 2 boilers of 150 horse-power, each. Of other equipment, the middle section may be mentioned, and consists of a locomotive house for 3 engines, containing also a 35 horse-power boiler, and pump for the supply of a water tank; a dynamite house—located half-way between the lower and upper pits; one large ore hopper, measuring 50 × 75 feet, served by 5 ton dumping cars on two tracks on top of hopper, with a total capacity of 1,000 tons. This ore house is located some distance below the big pits. A 350 ft. inclined tramway, with self-dumping cars, operated by a powerful 60 horse-power hoist, connects the hopper and mill.

The lower section comprises the extensive trestle work for the railway tracks; several cobbing sheds; a dryer building; a crusher building; the mill proper with ore bin; the dust chamber; the stock house; the big cobbing house; the machine repair shop; the coal bunkers, and all accessory sheds and buildings in connexion with the transport of the sand.

The milling process employed at the present time is the concrete result of several years experience and special experimenting on a large scale, and embodies the most modern features in the art of asbestos refining. The original mill as built in 1903 and 1904 had to be entirely remodelled and rebuilt, in order to meet the existing conditions and exigencies of the market; and even lately, considerable alterations were made. It will serve no purpose to enter here into details of the refining method; suffice it to state that, the capacity of the mill is 720 tons of mill rock per day, and that there are now installed: 2 Campbell rotary dryers; two big jaw crushers; a large gyratory mill, and six cyclones. The whole establishment is driven electrically: the crushing department by a 100 horse-power; the dryers by a 50 horse-power motor, and the mill proper by seven 100, one 50, and two 10 horse-power motors, the total motive energy amounting to 820 horse-power.

A 350 ton ore bin is placed between the crusher buildings and the mill proper, and distributes the asbestos rock directly to the cyclones. Of the other buildings in the lower section may be mentioned a complete machine repair shop containing all tools, metal, and wood working appliances, operated by a 25 horse-power electric motor; a large store shed capable of housing 20 carloads of asbestos —located on the main line of the Quebec Central railway; and a large central cobbing shed which receives the crude for additional treatment from all the smaller cobbing sheds distributed over the property.



Milling plant at the British Canadian quarries of the Amalgamated Asbestos Corporation, Black Lake, Que,

A novel feature of the works is, the manner in which the surplus sand—not sold—is disposed of. This sand is raised by an endless belt conveyer into a hopper on the elevated tracks, and is then carried by a 660 ft. centre to centre rubber belt conveyer to the end of the big dump, in the direction of the river. A turbine pump placed close to the latter, and driven by a 75 horse-power motor, forces water through a 6″ main, 1,000 feet long, to the top of the dump and the end of the belt conveyer; and from the latter is then sluiced down the valley by means of a powerful stream. The turbine pump, which can be driven by steam, in case of emergency, delivers water also to the main milling plant for fire protection.

Haulage of waste rock and ore all over the property is effected by three narrow gauge locomotives, and 60 4-ton dumping cars, the total length of track being 2½ miles. The Company has a number of small, well designed cottages erected for its officers and men in the immediate vicinity of the mill, which by their neat condition contribute in a large measure to the pleasing appearance of Black Lake.

The future policy in the development of the property is directed towards the exploration and opening up of the valuable ground below the upper pits: now covered by the immense dumps, resulting from the earlier operations. For this purpose an adit is driven from a convenient point below the dumps, 10 feet wide by 12 feet high, in the direction of the lower 'Manhattan' pit. This adit will have a length of 500 feet, and will connect with this pit by an upraise 30 feet high. This is an important step in the right direction; because it affords an opportunity not only of finding out what this ground actually contains, but a number of other advantages are gained thereby, namely, provision for underground work during the winter season, and cheap exploitation of the greater part of the upper asbestos bearing portion of the property.

The operations of the American Asbestos Company, and of its successor, the British Canadian Company, have been successful from the start. In 1907 the property produced about 5,000 tons of asbestos of all grades; the net profit for that year being $82,000, and for the year 1908, $142,000.

THE DOMINION QUARRIES.

Locality.—Black Lake, Que., on the mountain range south of Black Lake, adjacent to the Standard and British Canadian mines.

Superintendent.—W. A. Clearihue, Black Lake, Que.

Number of men employed.—Full force about 300.

There are a number of pits located on this property which have been previously operated on a considerable scale for the extraction of crude asbestos. The two lower pits have a total length of about 200 feet, and a width varying from 40 to 60 feet. The depth of these pits varies from 15 to 25 feet. A large number of veins of crude asbestos and milling fibre are in evidence over practically the whole face of the pits; and from these, the Dominion mill at present draws a large proportion of its supply of milling rock. At a distance of about 300 feet

from the above quarries, in a southeasterly direction, the productive serpentine formation has been worked for crude asbestos. The two upper pits—which are at present used for the storage of water—have a depth of from 40 to 60 feet. To the west of these pits several shallow openings and excavations exhibit veins of crude asbestos and milling fibre, all serving to demonstrate the continuation of the productive formation in that direction. In addition to the pits and openings enumerated, natural outcroppings are in evidence on the mountain slope.

It can thus be conservatively figured that the total area of productive rock already developed on the Dominion property extends over a surface of 600 feet in length by about 700 feet in width.

Beyond the elevation in a southeasterly direction, no effort has yet been made towards development; but asbestos has been found at a distance of 800 feet farther in a southerly direction, towards the crest of the hill, beyond the highest opening which has been made upon the Dominion property. This fact indicates that the asbestos-bearing rock on the Dominion property extends practically to the crest of the mountain range, which would more than double the productive area mentioned above. (See Fig. 6, page 74.)

A profile through the hill from the lowest workings on the plateau, to the point at which the present development has been carried on this property, shows a difference in elevation of about 200 feet. The physical advantages in the development are easily apparent to those familiar with the method employed in operations in the asbestos district; and future workings on the property will facilitate the opening of very large quarry faces, in such a manner as to provide natural drainage for the pits, and also for the transportation by gravity of the rock to the mill and dumps. This will constitute a very material saving in the cost of operations.

The pits are at present operated by three cable derricks, and two boom derricks, fully equipped with hoisting apparatus, boilers, steam drills, etc.

The crusher and dryer building, 32 × 72 feet, contains one large jaw crusher, and two duplex crushers, together with rotary dryers, furnaces, etc., complete. A belt conveyer runs from the building to a large ore bin adjacent to the mill proper, about 100 feet distant. This bin is of very heavy construction, and has a capacity of about 800 tons of milling rock. This is one of the specially advantageous features of the plant.

The Dominion mill has recently been completed, and is located in close proximity to the pits. This is the largest and most substantial structure of its kind in the district, 120 feet by 60 feet, four stories high with basement, with foundations of heavy concrete: the whole being of the most modern type of mill construction.

All the buildings above described are covered—both roof and sides—with asbestos protected metal, affording good fire protection.

The mill equipment consists of the following mechanical appliances: one pair of heavy rolls, 24″ × 40″, having a guaranteed crushing capacity of 25 tons per hour; the capacity of which can be raised to between 40 and 50 tons per hour —as recent tests of the apparatus have demonstrated; two pairs of rolls, 15″ × 30″, are placed on the third floor; and two pairs of rolls, of the same dimen-

sions, on the second floor; four special machines placed on the first and second floors; ten special fibre collectors 8′–6″ diameter by 12 feet high; two asbestos separators, together with the necessary conveying apparatus, screens, fans, etc.

The power equipment consists of a 100 horse-power motor for the operation of the dryers and crushers; a 300 horse-power motor for the operation of the mill proper, and one 10 horse-power motor for the operation of the conveying belt between the crushing house and the ore bin. The capacity of the machinery already installed is about 500 tons of milling rock per day of twenty hours. All the buildings referred to have been constructed of sufficient size and strength to permit of the installation of an additional unit, so that the present capacity can be doubled when occasion may warrant.

The system of separation in this mill is entirely different from that employed generally in asbestos mills; the cyclone machine—a most important apparatus in the asbestos mills—has been entirely dispensed with, and a system of rolls employed instead. The first pair of rolls has a crushing capacity of 25 tons of rock per hour; and two succeeding pairs of rolls finish the crushing to such fineness that all fibre in the rock is liberated. The advantage of this system consists in the preservation of the original natural fibre. A sample of this refined asbestos compared with asbestos from a cyclone mill showed quite a different appearance: exhibiting most of the coarse fibre—resembling 'crude,' and thus containing a higher percentage of long fibre.

It may be added that the location of the pits on a mountain slope offers great adavntages in the way of handling and transporting the ore to the mill, and in working the pits. There is no necessity for deep mining for some time to come, and if no mistakes are made in the system of exploitation, the gradually rising asbestos ground to a height of over 300 feet should provide exceptional facilities for cheap mining, in fact, should reduce the mining cost per ton of ore to the lowest possible figure. The advantages of the Dominion quarries in that respect are manifestly superior to anything in the district.

In addition to the above, there are upon this property, a commodious dwelling for the superintendent, and a boarding house for employes.

THE KING QUARRIES.

Locality.—Thetford, Que. Operating principally on lot 26, ranges V and VI, Thetford.

Manager.—B. J. Bennett.

Men employed.—Average, 700 persons.

The main quarry, which is now 1,350 feet long by 300 feet wide, and 190 feet deep, has been in operation for about twenty-five years: work having been begun in 1879, in a little ridge on the site of the present quarry.

It is reported that this large quarry has contributed one-third of the total production since the inception of the industry. A section of this pit, along its main strike, is shown on Fig. 18, page 106. Work towards depth and to the sides is conducted from a number of terraces; some of them attain, occasionally, a depth of 50 feet. The main trend of the big quarry is northwest 25°; and while the walls

of the pit do not strictly conform to a rectangular shape, the tendency is to cut through the rock in the main direction, with no regard to the occasional content of the rock. This facilitates mining to a great degree, and the works as carried on in this mine show great symmetry and uniformity in their general plans. All the cable derricks—15 in number—are of the tail rope type, and are placed in one line on the northeasterly side of the pit; they empty the boxes coming from the pit into 3 ton dumping cars, arranged on two tracks alongside the pit. The hoists, which are mostly of the 'special cableway hoist' pattern, are placed close to, and in rear of, the two-legged cable-way supports; but in the future a group of 2 or 3 hoists, serving as many cable-ways, will be placed in one building, on concrete foundations. A 14-drill Rand air compressor, driven by a Canadian General Electric motor of 600 horse-power, delivers air to all the drills—of which there are ten in operation, and to six cable-way hoists. This, together with a 15 horse-power motor for electric light, is housed in a substantial building close to the main pit, and covered with asbestos slate. A second power station is located at the northerly end of the pit, and consists of 2 Jenckes tubular boilers of 100 horse-power, which furnish steam to 4 hoists, and all the pumps.

The milling plant is located on both sides of the Quebec Central Railway track: the one on the southwesterly side consisting of rotary dryers, jaw crushers, and 6 cyclones. The crushers and dryers are actuated by a 25 and a 50 horse-power motor; while the mill proper is driven by a 350 horse-power motor. The mill building is covered with heavy corrugated iron. A big store shed alongside the track, and an office building, make up the balance of the plant on the southerly side of the railway track.

The mill on the north side of the track is the largest one in the district, and contains 8 cyclones; but instead of fiberizers, rolls are used. A 900 horse-power motor drives this mill; while a 50 horse-power motor runs the dryer and big conveyer belt. The two mills—the one on the south side and the big one on the north side—have a combined average capacity of about 1,700 tons of rock; but in case of need this capacity can be forced to a higher figure.

A pumping station at the river bank, which can be driven either by steam or a 50 horse-power motor, delivers water for all operative purposes, and for fire protection to the large plant.

There is a complete auxiliary steam plant with engines on the premises—in the event of the electric power giving out; but so far, there has been no necessity for calling the same into commission.

Haulage is done by 172 three ton dumping cars and 5 narrow gauge locomotives, communication between the south and north portions of the property, where the dumping ground is located, being effected through a substantial bridge over the tracks of the Quebec Central railway.

The King mines have at present the largest equipment in the asbestos district; and their output represents now fully one-quarter of the total Canadian production.

King's quarry of the Amalgamated Asbestos Corporation, Thetford, Que., looking west.

THE STANDARD QUARRIES.

Locality.—Black Lake, Que., on the hill facing the Quebec Central Railway station.

Superintendent.—W. A. Clearihue, Black Lake, Que.

Number of men employed.—Full force, 80 to 100 men.

Operations of this Company are carried on in a pit 300 × 150 feet, and from 70 to 80 feet deep, located on the top of the hilly serpentine ridge south of Black Lake station. Adjoining this, to the east, is another large quarry measuring 400 × 100 feet, with a depth of 40 feet; but not in operation. The quarry now operated exhibits an even uniform distribution throughout the rock of asbestos veins measuring from ¼″ to upwards of 2″ in width; and this even distribution is demonstrated by the records of the past operations of the Company. As an illustration, the average yield of asbestos fibre per ton of rock has run over 8 per cent for several years past, which is an exceptionally high showing.

The area productive of asbestos extends farther east, which can be seen in numerous outcrops, especially on the borders of the pit now used for water storage purposes. This pit, as well as some smaller ones, was worked many years for 'crude' only; and the rejected dumps from these operations close by, containing about 25,000 tons, give evidence of the richness in asbestos fibre of that portion of the property. In examining this property closely there is ample evidence that the productive asbestos belt extends to the extreme westerly boundary of the Standard Company's property; and beyond the line where several pits may be seen, containing some excellent asbestos veins. These numerous pits and outcrops are in evidence for practically the whole area of the hill, and cover a territory approximately 1,000 feet in length, by 600 feet in width. Basing the calculations on a depth of only 250 feet, and deducting about 250,000 tons from the total to provide for the rock already mined, about 7,550,000 tons of asbestos bearing rock are still left available within the limited area under consideration. If we reject 35 per cent as waste, and assume an 8 per cent extraction—as shown in previous records—we find that there are in this hill about 390,000 tons of asbestos, available for production.

The mine is equipped with 3 cable derricks of the 'tail rope' type. The mill is located close to the main quarry; in fact, the cable derricks are so close to the dryer building that they almost dump the rock from the boxes into the ore bin, an arrangement which tends to cheapen considerably the handling of the ore.

The dryer building contains 2 rotary tubes and a large jaw crusher, operated by a 40 horse-power electric motor. Immediately adjoining the dryer is the mill proper, measuring 80 × 40 feet, and four storeys high, including basement. This mill contains all the necessary machinery for the treatment of about 150 tons of rock per 24 hours, with a present average production of about 12 tons of fibre. The equipment consists of one Butterworth and Low crusher; one cyclone; and one pair of rolls, together with the necessary apparatus and appliances incidental to the proper freeing of the asbestos from the rock: such as screens, separators, collectors, and fans. The size of the mill building, and the present arrangement of the machinery are such as to allow of the installation of a comple second unit;

whereby the capacity of the plant may be doubled at a very reasonable cost. The mill is operated by a 150 horse-power electric motor. There is also a complete auxiliary steam plant, consisting of three 80 horse-power boilers, and a 200 horse-power slide valve engine. A small steam engine operates a dynamo for the generation of electric current sufficient for the necessary lighting equipment. The boiler plant is located in a power house entirely separate from the main building. The electric power used for the operation of the crushing, drying, and milling equipment, is at present supplied by the St. Francis Hydraulic Power Company.

The outside equipment, namely, the hoists, drills, derricks, etc., are operated by steam power.

A noteworthy feature of the milling plant is the ease with which the residue or sand is being disposed of. While in most of the operating mills special machinery and expensive conveying belts, etc., are installed for this purpose; at the Standard mill the residue is collected in the basement of the mill building, and is, owing to the advantageous natural formation of the land, easily and economically transported to the dumps.

Located on the property, in addition to the plant and equipment above described, are two large storage sheds, a blacksmith and carpenter shop, and a building for the storage of supplies; a small office building, and four dwelling houses. The Company has under lease to employes about twenty building lots upon which dwellings have been erected, and from the ground rent of which lots a satisfactory revenue is derived[1].

The Asbestos and Asbestic Company, Limited.

Locality.—Asbestos, Que., five miles from Danville, a station on the Grand Trunk railway.

Capitalization.—£500,000.

The control of this Company, originally an English concern, is now understood to be in the hands of the Johns-Manville Company, of New York.

(No further information available.)

Belmina Consolidated Asbestos Company, Limited.

Locality.—Five miles from Coleraine station.

Manager.—H. H. Williams.

Head Office.—Montreal.

Authorized Capital.—

Preferred stock, 7 per cent per annum	$ 600,000
Common stock	2,000,000
Total	$ 2,600,000
Bond issue: Authorized	300,000

of which $100,000 is reserved for future requirements.

[1] Since the above report was written an addional milling unit has been installed, thus doubling the output.

Mill at the Standard quarries of the Amalgamated Asbestos Corporation, Black Lake, Que.

Mining lands held.—About 900 acres, comprising the properties belonging originally to the Belmina Asbestic Company, and to the Asbestos Mining and Manufacturing Company: covering the northeast half of lot 25, range IV (about 100 acres); lot 24, range III (about 200 acres); lots 23 and 24, range II (about 400 acres); and the southwest half of lot 23, range I (about 100 acres): all situated in the township of Wolfestown, Que.

The properties originally belonging to the 'Asbestos Mining and Manufacturing Company' are located on the northeast half of lot 25, range IV, and were worked some twenty years ago for crude. It is reported that some 500 to 600 tons of this quality had been shipped from the mine during the course of these operations, and that in September, 1905, the erection of a large modern milling plant was proceeded with. The mill was completed by July, 1906; but owing to the difficulty in getting the necessary power, regular operations were commenced only in September, 1907, and continued until the spring of 1908. The capacity of the mill was 300 tons of rock in a 10 hour shift. A three mile road was built to reach the main road, the total distance to Coleraine station being about five miles. All the machinery was first run by steam; but owing to the scarcity of water, electric energy from the Shawinigan Power Company—who built a transmission line to the mine—was contracted for, and an electric plant installed by the Westinghouse Company. The principal pit is located on the side of a hill, and measures 110 × 125 feet, and is from 10 to 25 feet deep. The milling plant is located at a distance of 200 feet in westerly direction from this pit. The mill proper measures 40 × 105 feet and is four storeys high. The mill contains one 16″ × 30″ crusher; two 6″ × 20″ crushers; two 35″ × 36″ cylinder dryers; one 16″ belt conveyer from dryer to mill; a pair of 17″ × 36″ corrugated crushing rolls; two 20″ × 30″ high speed rolls; four beaters; one 16″ belt conveyer for sand; two cyclones; and the necessary exhaust fans, screens, graders, etc., also, one 75 horse-power, one 300 horse-power, and three 10 horse-power motors.

Besides the mill building proper the following structures are in close vicinity: one dryer building 30 × 100 feet; compressor building 30 × 60 feet; boiler house 30 × 60 feet; machine shop 30 × 60 feet; all containing the necessary tools for making repairs, lathe, drills, etc., and one 10 horse-power motor; men's sleeping quarters 35 × 100 feet; kitchen and dining room 40 × 70 feet; foreman's cottage 25 × 35 feet; one loghouse, and all the necessary sheds and houses in connexion with the mining property.

The other pit is located at a distance of 1,800 feet from the mill—in northwesterly direction: measures about 50 × 100 feet, by 30 feet, and is operated by three cable derricks. The ore from this pit is carried by a tramway down to the foot of the hill and there re-loaded by means of a hopper into dumping cars, which carry the material along the side of the hill to the milling plant.

Owing to the pits being filled with water, at the time of the examination, a complete inspection could not be made; but the writer was able to see some good veins delivering 'crude' of excellent quality for milling purposes: both in the lower and upper pits. It was reported that operations were suspended owing to lack of capital; but the writer is under the impression that, had the operations

been directed more with a view to development work than to the getting of immediate results, this property would have had a very different history.

'The Belmina mines' are located on lots 23 and 24 in range II. This property was worked, for 'crude,' quite extensively some twenty years ago. Three pits were in operation in the easterly slope of the serpentine range; and besides these three pits, there are a number of small cuts which were partly filled with water. Some excellent fibre was noticed, $\frac{3}{8}''$ and $\frac{1}{2}''$ wide, in a serpentine resembling that of Thetford; while innumerable smaller veins occur in different parts of these open-cuts, which had the appearance of excellent milling material.

The consolidation of these two mines, namely, the 'Asbestos Mining and Manufacturing Company' and the 'Belmina' asbestos properties, is, in the writers' opinion, a step in the right direction, and there seems to be little doubt that, with proper care, quite a workable area can be developed in a comparatively short space of time. The whole range upon which these quarries are located is composed of serpentine: in character similar to that found in the productive region of Thetford and Black Lake; and, as already stated, evidences of its productiveness may be perceived in many parts of the properties, especially on lots 23 and 24 of range II, and lot 25 in range IV.

The Beaudoin and Audette Asbestos Company.

Location.—One mile from Robertson Station, Que.

Manager.—A. E. Audette.

Head Office.—Robertson.

Incorporated.—1909.

Authorized Capital.—$500,000.

Mining lands held.—Mining rights on 200 acres on lot 9, range V, Thetford, Que.

Number of men employed.—40—all in construction work.

The mine is located at the foot of the Broughton range, which crosses the property in its northeasterly part. The principal pit measures 30 × 50 feet, and is in a light green, highly fissured serpentine containing vein fibre of greenish-white colour, but of excellent quality. Some spots in this pit are rich in asbestos fibre, and deliver in addition to 'crude,' a good milling material. A good deal of stripping has been done over the serpentine for a width of 120 feet, and a number of test holes indicate the continuation of the asbestos rock towards the west into lot 10—the King property. The width of the serpentine varies from 100 to 110 feet; but it is expected that continued exploration work will add to the productive area already available.

At the time of the visit of the writer, September, 1909, a mill for the treating of 300 tons of asbestos rock was under construction, and it is expected that this plant will be in operation during the winter of 1909-10. The size of the dryer building is 40 × 50 feet, and that of the mill building 40 × 96 feet.

The Bell Asbestos Company.

Now owned by the Keasbey and Mattison Company, of Ambler, Pa., U.S.A.

Locality.—Thetford Mines, Que.

General Manager.—George R. Smith, M.E.

Manager of Mines.—William Smith.

Head Office.—Thetford Mines, Que.

Not incorporated.

The Bell Asbestos Company, Limited, was originally an English Company and was capitalized at £250,000.

Mining lands held.—The principal asbestos ground held by this Company comprises lot 27, range V, Thetford township, covering an area of about 125 acres. Besides this, the Company owns several other asbestos lots in the township of Coleraine.

Number of men employed.—When working full, 450 to 500.

This is one of the oldest, and one of the most successful companies working in this district. Under the energetic management of George R. Smith, M.E., the Company have worked their way successfully through all the drawbacks which presented themselves in the early days when only the rough hand-cobbing and cleaning methods were in use. They were among the first to realize the immense advantage of mechanical treatment of asbestos rock; and when their mill was completed the enormous dumps from the earliest operations of the mine were at once turned into a realizable asset.

This Company, perceiving the great advantage which underground work would have in the winter season over open-cast work, commenced work in 1905, to cut through the great rock-mass bordering the large pit to the north; establishing at the same time a direct rail connexion between the pit and the mill. The whole plant and works are located in the southeasterly part of the lot; the Quebec Central railway dividing the works into two parts; the northerly one comprising the big milling plant, power house, machine repair shop, etc.; the southerly one consisting of the mining plant proper. The principal pit forms the northerly part of the great Bell-Johnson quarry. This main pit is connected with the mill through an inclined tunnel 560 feet in rock; the total length of the tramway between centre of main quarry and mill being 1,100 feet. (See Fig. 26, page 117). The difference in elevation between these two points is 169 feet, and the rise of the tunnel 12 feet to every 100 feet. In view of the discouraging results obtained some twelve years ago in a shaft which was sunk to a depth of 163 feet —close to the eastern boundary line towards King Bros. quarry, it was not expected that much valuable ground would be penetrated by this tunnel; but the excellent quality of the ground laid open completely discredited those early predictions. Credit is due George R. Smith, M.E., the present manager, for the zeal and remarkable insight he has shown in exploring a piece of ground which was supposed to contain poor asbestos. He was also the first to demonstrate the possibility, convenience, and economy of underground work in asbestos mining; which, up to that time, had been considered merely a miner's dream.

From the main inclined tunnel a system of almost parallel large roomy drifts is run, which are connected with each other at convenient intervals; the total length of underground works amounting to about 1½ miles. In this way quite a large piece of ground, 900 × 700 feet, and 170 feet deep was explored; which is now separated from the main quarry by a granite dike 30 feet wide, running almost parallel with the main trend of the latter. It is stated that the ground thus opened up is far richer than that met with in the old quarry to the south of the dike; especially so along the latter, where rich accumulations of veins are encountered. A visit to the underground workings will convince anyone familiar with the conditions governing the occurrences, that the Bell underground workings have, at present, the best showings of rich, silky, asbestos veins in the whole region, and for that matter in the whole world. There is no place where such an exposition of substantial veins of the highest quality fibre can be seen. Moreover, the distribution of the veins over the whole area under exploitation seems to be pretty evenly divided, which should facilitate the exploitation of these deposits towards depth. Parts of the drifts and the large tunnel are illuminated by 400 lights—each 16 candle power.

There are two quarries in operation during the summer season. The main quarry, into which the tunnel leads, measures about 650 feet long, 250 feet wide, and about 200 feet deep. The other quarry is located close to the large one, right in the corner of the property, bordering the Johnson mine to the south and the King Bros. mine to the east. Its measurements at the time of inspection were 300 feet by 200 feet, and 80 feet deep. All the cable derricks—11 in number—mostly of the return cable type, are placed on the northwesterly sides of the pits: the cable towers being all of the pyramid or four-legged type.

The power plant, for the mine proper, consists of two tubular boilers, having a total capacity of 225 horse-power; which feed altogether 12 hoists for the cable derricks.

A large store house, carpenter shop, and office building make up the balance of the plant on the south side of the track of the Quebec Central railway.

A new office building, one storey high, measuring 90 × 40 feet, is now being built close to the Quebec Central Railway track. A special feature in the construction of this building will be, the free uses of asbestos shingle sheathing and flooring; and with the exception of the floor beams, all the materials used will be absolutely fireproof.

The milling plant, power house, store, and repair sheds, are located on the north side of the railway track. The power plant for the large 500 ton mill, consists of three 100 and two 125 horse-power, return tubular boilers, having a total capacity of 550 horse-power. The mill engines are 2 Laurie Corliss engines: one of 350 horse-power, and the other 150 horse-power.[1] A 10-drill compressor plant completes the machinery in the main power house. The latter is built of wood, covered with asbestos shingle roof and corrugated asbestos sides: manufactured by the Asbestos Shingle, Slate, and Sheathing Company, Ambler, Pa., U.S.A. The mill has a capacity of 500 tons of asbestos rock per day, and is com-

[1] Since writing the above the steam plant for the mill has been replaced by electric power.

Mining and milling plant of the Berlin Asbestos Co., near Robertson Station, Que.

posed of a steam pipe dryer; jaw crusher; gyratory; 3 pair of rolls; 3 rotaries; and 4 cyclones. The new machine shop contains all apparatus and machinery, drill presses, planers, etc., for making heavy repairs; while the carpenter shop contains a complete saw and planing mill. A new asbestos mill having a capacity of 600 tons of rock per day is in course of construction, and will be ready in the summer of 1910. Transportation of the ore to the mill is effected through 170 4 ton dumping cars, and 5 geared locomotives (system Smith): three of which have 42½″ gauge, and two, standard gauge.

The Berlin Asbestos Company.

Locality.—Three miles northeast of Robertson Station.

Managing Director.—George Rumpel, Berlin, Ont.

Authorized Capital.—$600,000.

Incorporated.—1909; Quebec charter.

Head Office.—Berlin, Ont.

Mining lands held.—118 acres in fee simple, covering east half of lot 2, range V, township of Thetford, Que.

Number of men employed.—40—all on construction work.

The Company have done some development work since April, 1909, on their property in the serpentine belt, which traverses it at a distance of 1,500 feet from the main road 'Robertson-Broughton.' So far, the belt shows a width of 150 feet. The serpentine is much fissured and crushed, and contains a fine white asbestos fibre of the slip fibre quality. A test with 16 tons in the mill of the Eastern Townships Asbestos Company, at East Broughton, gave 8 per cent of asbestos of all grades.

Work on the foundations for a 4 cyclone mill has just commenced, and it is expected that the plant will be ready for operation in the spring of 1910.

The Black Lake Consolidated Asbestos Company.

Locality.—Black Lake, Que.

Manager.—Edward Slade.

Incorporated.—Under the laws of the Dominion of Canada.

Capitalization.—

Preferred stock: entitled to non-cumulative dividends at the rate of 7 per cent per annum		$ 1,000,000
Common stock		3,000,000
Total capitalization		4,000,000
Bond issue authorized	$ 1,500,000	
Reserved for future requirements		500,000
Issued		1,000,000

Mining lands held.—

Black Lake:	The Union Asbestos mines.. ..about	110	acres.
"	The Southwark mines....... "	117	"
"	The Imperial Asbestos Company " (The controlling interest in)	158	"
"	The Black Lake Chrome & Asbestos..................	5,000	
	Total.............	5,385	"

This Company was formed in the spring of 1909, and bought all the properties belonging to the Black Lake Chrome and Asbestos Company; the Union and Southwark Mines; and the controlling interest in the Imperial Asbestos Company, whose property is located on the Quebec Central Railway track, one mile south of Black Lake village.

The Union and Southwark quarries.—These properties have been worked intermittently for the last twenty years. Evidence to this effect may be seen in the numerous pits distributed over lots 27 and 28, range B. A great deal of work has been done, especially in the Union quarries on the west halves of lots 27 and 28, comprising about 104 acres. Eight pits have been made all along the mountainous range which faces Black Lake village to the east. The largest of these pits—No. 8, is the main working pit of the mine, measuring 210 × 350 feet; and is reported to have yielded satisfactory returns. All the output was handled in a small, one cyclone mill; but this is to be dismantled in the near future. In addition to this developed area there is a stretch of virgin asbestos ground farther back on the hill; but which has not been touched yet. Dumps of considerable extent have been accumulating for the last twenty years; and although a large quantity of this material has been treated in this comparatively small mill, there still remains a large tonnage to be utilized.

The Southwark quarry.—This quarry occupies the eastern halves of lots 27 and 28, adjacent to the Union quarries; covering about 100 acres. This property was worked many years ago for crude only: at a time when the residue was thrown to the dump owing to the lack of treatment facilities. A considerable amount of work has been done all over this property, which shows in a more or less degree the existence of good available mill rock and crude. This is especially evident along the line of the Union Asbestos quarries, where numerous small pits exhibit the quality of the work. Besides these smaller pits, there are about eight larger openings. One pit measures 60 × 80 feet, and 15 feet deep; another 50 × 50 feet, and 10 feet deep; a third one 30 × 50, and 15 feet deep. The most important pit is located near the eastern boundary of the property, and occupies an area 45 × 85 feet, with rock faces up to 35 feet high. Quite a number of asbestos veins can be seen all over this pit, and it is evident that, the rock will yield quantities of crude asbestos.

At the time of this writing a large milling plant is in course of construction close to the dividing line between the Southwark and the Union quarries, in the lower part of the latter. This milling plant will consist of one bin containing

350 tons of rock; a crusher building; a dryer building; another 850 ton ore bin; a re-crushing building; and the main mill building, the latter 84 × 120 feet; and three stories high. Six cyclones of a new approved design will be installed. Communication between the eastern part of the Southwark mines and the mill is effected through a tramway three-quarters of a mile long.

The Imperial Asbestos Company.

Locality.—Three-fourths of a mile southwest of Black Lake station, on both sides of the Quebec Central main line.

Authorized Capital.—$1,000,000.

The controlling interest in this Company was acquired recently by the Black Lake Consolidated Asbestos Company.

The property has the shape of a triangle: the broadest side of which follows parallel to the sinuosities of the Quebec Central Railway track, and east of the same at a distance of about 400 feet. Some twenty-two years ago the property was worked for 'crude,' and evidences to that effect may be seen in the many pits, open-cuts, strippings, and excavations all over the property.

Exploration and development has been in progress since the spring of 1909, and this work has added further evidence of its value as a producing property. It constitutes part of the hillside of the mountainous range which strikes through the country in a southwest, northeasterly direction to the south of Black Lake station. Some twenty pits, distributed over an area approximately 1,200 feet long, and 400 feet wide, demonstrate the existence of a large body of asbestos mill stuff.

This property has many of the advantages which are essential to success in mining: (1) the main line of the Quebec Central traverses the property, thus ensuring cheap transportation; (2) its location on the mountain slope affords cheap mining and hauling to the mill, and (3) excellent dumping facilities on the low lying lands close to the lake.

The construction of a 4 cyclone mill in the near future is in contemplation.

The Boston Asbestos Company.

Locality.—Half a mile from East Broughton station.

Manager.—A. A. Normandin.

Head Office.—Levis, Que.

Incorporated.—1907, Dominion Charter.

Authorized Capital.—$300,000.

Mining lands held.—25 acres east part of lot 13c, range V; 100 acres, whole of lot 13b, range V; 140 acres, whole of lot 14a, range V.

Number of men employed.—70.

The principal pit now in operation is located on the east half of lot 13, range V, close to the concession road. Ore is transported during the winter season to the mill, which is located on the west half of the same lot, three-fourths of a mile distant; but it is the intention of the Company to build either a narrow gauge

tramway or a cableway. The deposit worked is remarkable in many respects, and differs considerably from all other deposits of slip fibre worked in the district. The serpentine is highly fissured, and contains a white, silky, asbestos fibre. Some of it, especially that found near the surface, is to some extent brittle, suggesting picrolite; but it appears that less of this mineral is present as depth is gained. The deposit is located close to the southerly contact of the schist formation.

The milling plant is located on the main line of the Quebec Central railway; has a capacity of 300 tons in double shift, and contains the following principal apparatus and machinery: one 'Campbell' (5 tube) dryer, and 2 jaw crushers: all actuated by a 50 horse-power engine, and housed in one building; a rotary crusher; 2 fiberizers; 2 cyclones, with the necessary accessories; all in a 3 storey mill building 105 × 50 feet. The mill engine is a 300 horse-power 'Jenckes' Corliss engine. The power plant consists of 2 Jenckes horizontal tubular boilers, of 150 horse-power each. The balance of the plant is composed of a blacksmith and general repair shop; inclined railway to cable derrick located on upper pits; and hoisting plant. The Company has also erected a fine office building, and residence for the manager.

The Broughton Asbestos Fibre Company.

Locality.—Three-fourths of a mile from East Broughton.

Manager.—Col. H. H. Williams, C.E.

Head Office.—Portland, Me., U.S.A.

Incorporated.—July 4, 1907, Quebec charter.

Authorized Capital.—$500,000.

Mining lands held.—35 acres in fee simple on lot 13, range VII, Broughton township, Beauce county.

Number of men employed.—Full force, 85.

In 1891, Col. H. H. Williams, the present manager, worked on a spot, where the lower pit is now located, in a small pit—with 12 men and a boom derrick—from which some 60 tons of excellent crude asbestos were taken out. At that time, however, the demand for asbestos was very slack, and much difficulty was experienced in selling the crude at fair prices. This caused a suspension of work during the following ten years, and operations were not resumed until the year 1901, when the present Company commenced business again on a small scale. Several pits were worked, and a trial plant installed. The latter was subsequently enlarged to a daily capacity of 125 tons; but was destroyed by fire early in 1904. This plant was rebuilt in 1905, and the Company, realizing the ever increasing demand for their products, enlarged and thoroughly equipped the milling plant, in 1907, to a capacity of 350 tons of asbestos rock per day.

At present, two pits are in operation close to the boundary line of the Glasgow and Montreal Asbestos Company, and along the southern contact with the schist formation. The upper pit measures 200 × 75 feet, and the other one, close by, 400 × 100 feet, the depth varying between 40 and 60 feet, The quarry equipment consists of 3 cables; 2 boom derricks; 5 hoists; one locomotive, and 15 self-dumping cars—holding 5 tons each. The mill consists of two principal

PLATE LIV.

Plant of Broughton Asbestos Fibre Co., East Broughton, Que.

buildings: the dryer, and crusher buildings—36 × 96 feet—and the mill proper. The former are equipped with 6 tube dryers and 2 jaw crushers, actuated by a 100 horse-power, high speed engine. The mill proper contains 2 Butterworth and Low crushers; 2 fiberizers; 3 cyclones, two of which are permanently in operation, and one in reserve; and all accessories. The capacity of the mill engine is 200 horse-power. Steam is furnished by three boilers, each 100 horse-power capacity, and one smaller boiler of 70 horse-power. The balance of the plant is made up of blacksmith, carpenter, and general repair shops; store house, and office building, also a sand conveyer and hopper. The Company has lately erected a boarding house, 48 × 30 feet, for the accommodation of twenty-six men, also a handsome manager's residence. A siding one-half mile in length, owned and operated by the Company, connects the milling plant with the main line of the Quebec Central railway; and a large storehouse having a capacity of 300 tons has lately been constructed, at the junction of both.

Coleraine Exploration Company—(Operations Suspended).

Locality.—One and a half miles from Coleraine station.

Owners.—The Black Lake Chrome and Asbestos Company, and the Premier Mining Company.

Head Office.—Black Lake, Que.

Mining lands.—120 acres in block B, Coleraine township, Megantic county, Que.

The principal pit is located on the property of the Premier Mining Company, a little west of the milling plant, and measures 135 × 75 feet, and from 10 to 20 feet deep. The asbestos occurs here for the greater part in pyroxenic seamy partings, cutting through a hard, dark green serpentine, in irregular fashion. On the westerly wall of this pit some good asbestos veins occur, over an area 12 × 15 feet square. Most of them have a dip of 65° north; and they are approximately parallel to each other, and constitute part of a good pay chute.

In a northwesterly direction from the mill, on the crest of a hill, another pit has been in operation for some time. A tramway three-fourths of a mile long, connects pit and mill. This pit has a rather peculiar showing of asbestos. Three veins from ⅜″ to ¾″ wide, occur parallel to each other, over a band of serpentine 4 feet wide. This band, which forms a part of a serpentine ridge, strikes east and west, and dips to the north under an angle of 12°. Several adits, 7 feet high, and distributed over a rock face 95 feet long, have been driven into this serpentine band, following its dip to a depth of 60 feet. A distinct fault has thrown this banded arrangement out of position for about 10 feet; the fault dipping slightly towards the east, cutting the lode at almost right angles.

Besides these underground works, there are quite a number of pits distributed over an area measuring 205 feet long by about 100 feet wide. All these pits, in a more or less degree, show asbestos veins of good quality; but it appears that several places have been gouged.

The plant consists of the mill proper; dryer building; boiler house; cobbing

house, and office. The mill contains 2 jaw crushers; 1 fiberizer; 1 cyclone; with all accessories. The mill engine is of the slide valve type, 75 horse-power; the dryer and crusher are driven by a 25 horse-power engine. Steam for these engines is supplied by a 100 horse-power tubular boiler.

All the machinery plant, and the upper pit, are located on ground belonging to the Black Lake Chrome and Asbestos Company.

D'Israeli Asbestos Company.

Locality.—Five miles distant from the village of D'Israeli, Que. Wolfe county, Que.: comprising about 275 acres.

Head Office.—D'Israeli, Que.

Incorporated.—1908.

Authorized Capital.—$900,000.

Mining lands held.—Lots 16, 17, and 18, range III, Garthby township, Wolfe county, Que.: comprising about 275 acres.

Number of men employed.—25—all on construction work.

This Company has done some work in the northern part of lot 16, range III; consisting of open-cuts, blasting, and excavations in a hill of serpentine. The largest opening measures 20 × 40 feet, and is in a dark, mottled green, fibrous serpentine, similar to the East Broughton variety. There is a large development of this rock all along the road; its contact with the country formation can be well seen towards the east. This contact consists of feldspathic grey and quartzitic rocks, with a strike northeast 60°, and an almost vertical dip. At the time of the writer's visit in September, 1909, a mill was in course of erection, 400 feet south of the serpentine hill. This mill building measures 50 × 100 feet; is three stories high, and will ultimately contain 2 cyclones, with all the necessary machinery. The dryer building is 45 × 65 feet, and will contain 2 tubular dryers with all necessary crushing machinery.

Eastern Townships Asbestos Company.

Locality.—East Broughton, Que., on the Quebec Central railway, sixty miles from Quebec, and eighty-three miles from Sherbrooke.

Managing Director.—Philippe Angers, Beauceville, Que.

Head Office.—East Broughton.

Incorporated.—June, 1907, under the laws of the Province of Quebec.

Authorized Capital.—$240,000.

Mining lands held.—90 acres in fee simple on lot 13W, range VI, Broughton township, Beauce county.

Number of men employed.—Full force: 30 in mine; 10 in mill.

This property was tested several years ago; but actual operations by the new Company began only in the autumn of 1907. The principal band of productive fibrous serpentine on this property is the extension of the Ling Asbestos Company's deposit, which is being operated to the northeast. While the principal pit is located on what may be termed the northern limit, other outcrops all over the

New mill of Black Lake Consolidated Asbestos Co., Black Lake, Que.

property point to the occurrence of asbestos-bearing serpentine in tne centre and towards the southwest of the property. The present pit is located on the south-easterly part of the property, not far from the main road. Crude fibre of excellent quality is being found all along the contact with the schist formation; and it is likely that similar conditions may be found, as in the Fraser quarry on the adjoining property, which at one time produced beautiful crude fibre. The serpentine shows a great many slickensides, and other evidences of crushing and displacement movements.

The mill is conveniently located in the centre of the property, and receives the crushed rock by means of a belt conveyer from the dryer. The rock from the mine is lifted by cable derricks to a high trestle, and transported by ore cars to the ore bin of the dryer building. Here, the rock passes first through a crusher, then through a dryer, again through crusher, and from thence by belt conveyer to a Butterworth and Low rotary. The subsequent treatment is performed through fiberizers, 2 cyclones, a number of screens, and collectors. The capacity of the mill is about 300 tons daily, in double shift, yielding about 30 tons of asbestos. The power plant consists of 2 boilers having a total capacity of 250 horse-power; also a mill engine, with all accessories. It is the intention, however, to replace steam by electricity as soon as a power line is built by the Continental Light, Heat, and Power Company, from their main station at Thetford—sixteen miles distant.

The Frontenac Asbestos Mining Company.

Locality.—Close to East Broughton station.

Managing Director.—A. Campbell, Quebec.

Resident Engineer.—H. C. Riehle.

Head Office.—Quebec.

Incorporated.—In 1907, under the laws of the Province of Quebec.

Authorized Capital.—$500,000.

Mining lands held.—130 acres in fee simple, covering the east half of lot 13, range VI, Broughton township, Beauce county.

From outcrops on the surface in the westerly part of the property, it appears that this ground is a continuation of the asbestos belt on which the Ling Asbestos Company is working. The extent of the asbestos bearing ground is approximately 150 feet wide, by over 2,000 feet long. The southern contact of the main upper asbestos belt with the Cambrian schist formation strikes northeast 60°, and has a dip of 65° to the south; indicating, apparently, that the productive formation widens out with depth. Besides this belt there are a number of outcrops of asbestos to the south of the contact, belonging to a separate strip of serpentine; but parallel to the main belt. A 500 ton modern milling plant, just completed, is located south of the main belt. A siding, 1,600 feet long, connects the plant with the main track of the Quebec Central railway.

Operations are carried on in the following order: 4 cable derricks, resting on towers 55 feet high, hoist the material from the main pit, which is located along the contact-formation, and place the same on cars moving on a bridge 750

feet long, and propelled by an electric locomotive. The material is dumped into a 450 ton ore bin, then passes through a jaw crusher 15″ × 30″; 2 Campbell dryers; and 2 rotary crushers: the whole actuated by a 150 horse-power motor. A bucket elevator carries the crushed ore to an 800 ton ore bin; whence it is again elevated by a rubber belt conveyer to a third ore bin on the top of the mill building. This ore bin distributes the ore to four units through four separate ore feeders; each unit consists of 1 fiberizer, 1 cyclone, and the necessary screens and fibre collectors: the whole being actuated by 100 horse-power motor. The cleansing screens are divided into 2 extra units, each driven by a 50 horse-power motor. Fifteen fans, 10 fibre collectors, 1 elevator, and 1 bagging apparatus, form the accessories to the plant.

The size of the dryer building is 46 × 71 feet, and of the mill building 50 × 100 feet.

The hoisting and drilling machinery is actuated by compressed air. The compressor plant consists of 1 Rand-Drill Air Compressor, of capacity=1,150 cubic feet per minute (for 10 drills), actuated by a 200 horse-power motor, The hoists—four in number—are of the Flory Tandem Drum type, cylinder 12 × 12 feet, each 50 horse-power. A 50 kw. direct current generator furnishes power to the electric locomotive on the bridge. The compressor plant is housed in a building 42 × 60 feet. Building, as well as machinery, rests on concrete foundations.

The whole plant is laid out in such a manner that the material is handled quickly and economically.

The Jacobs Asbestos Mining Company of Thetford, Limited.

Locality.—Thetford, Que.

President.—J. A. Jacobs.

General Manager.—Walter Kerr.

Assistant Manager.—W. Leventritt.

Head Office.—171 St. James Street, Montreal.

Incorporated.—Under the laws of the Province of Quebec.

Authorized Capital.—$3,000,000—all common stock.

Mining lands held.—128 acres, lot 28, range VI, township of Thetford.

Number of men employed.—On stripping and construction work, 225.

The ground upon which this new corporation is working adjoins the Beaver quarries of the Amalgamated Asbestos Corporation to the east. The northern part was worked for 'crude' early in the nineties. Evidences to that effect may be seen in one large pit, which exhibits a number of asbestos veins of excellent quality, and of satisfactory width. The new corporation stripped a great deal of the ground adjoining this pit, and quarried part of it during the summer of 1909. The results were so encouraging, that now, a large milling plant is under construction; which will be in running order in the spring of 1910. The workable area so far laid out for immediate production, measures 300 × 600 feet; and according to Mr. Kerr—the general manager—246 tons of crude were taken from the pits during the summer season of 1909—up to the fifteenth of November.

Nine cable derricks are being installed along the border of the long pit, each driven by a 60 horse-power electric hoist.

The milling plant is one of the largest in the Thetford-Black Lake district, and embodies all modern improvements in asbestos milling practice. It is divided into two parts: one, comprising the preliminary crushing and drying operations, located on the northern side of the Quebec Central Railway track; the other, the mill proper, located on the southerly side of the latter. Connexion between both establishments is effected by a 30″ overhead conveyer, 285 ft. centres, rising with an angle of 17°.

The northerly part of the mill comprises: one 24″ × 36″, and one 36″ × 18″ Farrel jaw crusher: both placed on heavy concrete foundations; bucket elevators, and two dryers: one, an ordinary 5 tube ‘Campbell; the other a ‘Campbell’ with fan attached. A Laidlaw compressor delivering 1,250 cubic feet of air per minute, housed in the same building, furnishes the necessary power for the machine rock drills.

The plant is so arranged that the rock coming from the quarry, if sufficiently dry for milling, can pass direct from the big jaw crushers, over the main 30″ belt to the mill.

The electric power equipment for this machinery consists of one, 150 horse-power motor to drive the crushers; one 50 horse-power motor for the dryers; and one 250 horse-power motor for the compressor. All this machiney is housed in a building 56 × 70 feet.

The mill proper, on the south side of the railway track, is of a somewhat irregular shape; resulting from the almost unique arrangement of the different milling machinery employed. Two small ore bins receive the rock from the 30″ conveyer; and any overflow caused through temporary mill stoppage, or other causes, is delivered into a huge 800 ton reserve ore bin. The mill stuff is handled by two separate units: each unit consisting of four gyratories: care being taken that the fibre is separated from the rock after each crushing operation and placed into the collecting chambers; 3 cyclones, and all the necessary screens, sieves, fans, and collectors.

Each gyratory is actuated by a 100 horse-power motor; and each of the 6 cyclones by a 125 horse-power motor. A modern feature of this mill is, that the entire electric power equipment is placed in a compartment entirely separate from the mill operations, thus protecting the electrical appliances against the sharp, flying, asbestos dust.

The main building measures 96 × 180 feet, and is a very substantial structure, placed on heavy concrete foundations. The tailings of the mill are handled by an automatic aerial bucket conveyer, which permits of a dumping height of over 100 feet. Twenty-two motors of 2,075 total horse-power are distributed over the whole mining and milling plant; the ultimate daily capacity being 750 tons of mill rock.

The Johnson Asbestos Company.

Locality.—Thetford, Que.

Manager.—A. S. Johnson.

Head Office.—Thetford, Que.

Incorporated.—Under the laws of the Province of Quebec, in 1885.

Authorized Capital.—$250,000, all paid up.

Mining lands held.—Over 1,000 acres in Thetford and Black Lake. The principal mine is located on the northeast portion of lot 27, range VI, Thetford township.

Number of men employed.—Full force at the Thetford mine, 175; at the Black Lake mine, 125.

This Company was the pioneer in the asbestos industry: their operations having commenced in 1878. At present, two quarries, with separate plants, are in operation: one at Thetford, and the other at Black Lake; the Thetford plant being the larger. At the Thetford mine the main quarry is located along the northwesterly boundary line, and is separated from the great quarry of the Bell Asbestos Company only by the narrow ridge of a granitic strike in the direction of the east-west line. In shape it is irregular: having a total length of 750 feet, and width of about 350 feet. Four pits are being worked inside the quarry at the present time, and their varying depths admit of a systematic exploitation of the asbestos deposits. Nine cable derricks—mostly of the stop-log type—are in operation. The majority are located in the southerly side of the quarry; thus facilitating and concentrating the hoisting and transportation of the rock. They are operated by 9 hoists, most of which are located close to the derricks. One power station contains 3 cable hoists and 2 Jenckes boilers, of 250 horse-power, which also deliver steam to 5 machine drills. The serpentine sometimes shows small dikes of granulite, running through the rock in irregular fashion. The ground in which this quarry is being worked is considered one of the richest in the district. The Company is reported to have shipped more crude than any other concern, and the product is known for its quality all over the civilized world.

The extension of asbestos bearing ground towards the south is established by several outcrops which were accidentally discovered by making a deep ditch for a pipe line across the property.

The output of milling material is handled by two mills: one—the old mill near the western quarry—having a capacity of about 200 tons of rock per day, and another mill, partly rebuilt lately, with a capacity of about 500 tons, in double shifts.

The plant in the older mill consists of two horizontal boilers; one 50 horse-power Corliss mill engine, driving a rotary dryer, 18 feet long and 30″ diameter; dynamo; and crusher; and a second Corliss mill engine of 90 horse-power, driving the mill proper: which contains 2 jaw crushers; 2 pairs of belt rolls; picking tables; fiberizers; screens; blowers, etc.

The other 500 ton mill is located at a distance of 800 feet south of the big quarry, and consists of two separate sections: the crushing and the fiberizing

mills—the latter being of recent construction and forming a complement to the older mill or crushing department. It must be stated that this new addition—the fiberizing plant—is one of the most substantial and secure structures in the district: the main driving shaft is placed on the ground floor on solid concrete piers, and runs the full length of the building, dispensing power to all mechanical appliances and apparatus throughout the mill. This is a novel feature: for it undoubtedly eliminates all unnecessary vibration, and reduces it to a minimum. The power plant consists of 3 Babcock and Wilcox boilers, each of 300 horse-power; and 2 Jenckes, horizontal tubular boilers, each of 200 horse-power—the whole representing 1,300 horse-power.

The motive power for the new addition—the fiberizing mill—is provided by a Bellis and Morcalm (Birmingham) 450 horse-power reciprocating engine; while the old mill or crushing department is driven by a 300 horse-power Jenckes Corliss engine. A 45 horse-power steam engine actuates an electric light dynamo, which furnishes electricity during the day time for the machine shop; that is being equipped with all appliances for making new machinery, and most of the repairs. Haulage is done by 3 locomotives, and 70—3 and 4 ton—dumping cars.

The dumping ground is placed outside the range of the present workings, in a southerly direction. As there is no sloping ground on the property, all the tracks to the new mill and dryer are elevated; a large part being on trestles, thus allowing the rock to be dumped directly into the ore bins.

Apart from the above-mentioned main buildings, there are, on the ground, two large store houses; carpenter's shop; girl's cobbing-shed; men's cobbing-shed, and a number of small buildings for hoists and accessories.

The miners live near the mine in comfortable houses built and owned by the Company. These houses form a conspicuous part of the town of Thetford, and their neat, clean condition, contributes in a large measure to the generally comfortable appearance of that place.

The Johnson mine at Black Lake is located on lot 27, next to the property of the Union Asbestos Company. The main pit on the slope of a hill measures about 350 × 200 feet, and about 100 feet deep. Asbestos occurs in veins running in the centre of seamy partings, similar to those described on pages 49 and 50. At one place, seven veins from ½″ to 1½″ wide, and running parallel to each other, were observed, covering a total width of 12 feet. The serpentine is massive, and exhibits, in a less degree than is observed elsewhere in the district, the effects of crushing or displacing forces; hence most of the veins appear in their original deposition. Five cable derricks are in use, operated by 2 special cableway hoists and 3 double drum hoists. After extraction of all the crude by hand, the fines and the milling rock are dried in a rotary dryer, which is placed in a separate building near the quarry, and from thence they are transported to the mill. This is a four storey building, and contains all appliances for the handling of 250 tons of asbestos rock in a double shift. No cyclones are used; the fine crushing being done in belt rolls and fiberizers. The boiler plant for the mill is composed of two horizontal boilers of 125 horse-power: each provided with feed water

heater. There are two mill engines—each 150 horse-power tandem compound. The mill is lighted by electricity, generated by a 100 light dynamo, and driven by a 10 horse-power high speed engine.

The Ling Asbestos Company.

Locality.—Near East Broughton station.

Superintendent.—John Penhale.

Head Office.—East Broughton, Que.

Authorized Capital.—$200,000; Bond issue, $200,000.

Mining lands held.—64 acres on west half of lot 13, range VI—in fee simple.

Number of men employed.—70.

Operations were commenced on this property in 1904, and, with few interruptions, have been carried on ever since. The main pit is located in the northeasterly part of the property, along the southerly contact with the schist formation; has a main trend of northeast 50°, and measures 325 × 100 feet, and 60 feet deep. The serpentine contains 'slip' fibre abundantly distributed through it; the extraction keeping well over 7 per cent and sometimes reaching 12 per cent. Some of the fibre occurs occasionally in veins showing the effects of rock pressure and displacements; but not in such quantities as to invite the production of 'crude.' All the rock passes through the mill, and delivers white silky fibre of excellent quality.

The big quarry is operated by 2 cable derricks of the tail rope type. The milling plant consists of dryer and crusher building; the mill proper; and the power house. The following appliances and machinery are installed: 2 jaw crushers; 1 (5 tube) Campbell dryer; rotary crusher; a 16″ rubber belt conveyer; fiberizer; 3 cyclones, and all accessories; a 250 horse-power Corliss mill engine; and a 15 horse-power engine which drives a 200 light dynamo. The power house contains 2 Jenckes tubular boilers, having a total capacity of 300 horse-power. The finished product is carted to the station grounds, where the Company has erected a storehouse 100 × 50 feet.

The Robertson Asbestos Company.

Locality.—Four miles from Thetford, Que.

Managing Director.—J. R. Duckett, Montreal.

Superintendent.—W. J. Woolsey, M.E.

Head Office.—Thetford Mines, Que.

Incorporated.—Under the laws of the Province of Quebec.

Authorized Capital.—$950,000.

Mining lands held.—800 acres, comprising lots 13, 16, and 17, range IV; and lot 13, range V, in the township of Thetford.

Number of men employed.—140.

This Company commenced operations late in the spring of 1908, on lot 16, range IV, and it is a sign of remarkable energy and enterprise on the part of Messrs. Duckett, and W. Smith—the then resident manager—that during the one year following, not only was the property thoroughly explored and developed

Six cyclone milling plant of the Robertson Asbestos Co., Robertson Station, Que.

for future operations, but a modern 400 ton mill with all camp buildings was completed as well; thus allowing the beginning of actual work in the month of June, 1909.

The mill is unique in its construction, and the only one of its kind in the district. Mr. W. Smith—now manager of the Bell Asbestos Mines—was the designer: having had a most varied experience as a mill superintendent covering a period of many years. He conceived the new idea of dividing the separation of the fibre from the rock into three distinct operations: (1) the crushing and drying; (2) the re-crushing, and (3) the final disintegration in cyclones.

The mill is located in the southern part of the property, on a gentle slope; the mill stuff being delivered from the mine over an elevated track direct into the ore bin of the crusher and dryer building. The latter measures 30 × 70 feet, and contains one Farrel crusher 30″ × 16″; another Farrel crusher 16″ × 10″, and one Campbell dryer, actuated by a 100 horse-power motor.

The recrushing building measures 42 × 54 feet, and receives the rock in a 200 ton ore bin, through a 24″ rubber belt conveyer. The rock then passes through a sizing sieve; the oversize being treated in a No. 3 crusher, and the fine material from the sieve as well as from this crusher falls on a 4 × 10 ft. screen, where, for the first time, the liberated asbestos fibre is taken up through suction. All material is then treated in a second No. 3 gyratory, and subsequently in a Butterworth and Low rotary; care being taken that in all these operations any freed fibre is taken up from the sieves by suction. A 100 horse-power motor drives all crushers, sieves, and screens, in this building.[1]

A 16″ belt conveyer driven by a 10 horse-power motor carries all the material from the recrushing building to the ore bin of the cyclone building; the latter measuring 40 × 52 feet. Two cyclones mounted on solid concrete foundations, and each driven by a 100 horse-power motor, finally disintegrate the material; while six 6 × 12 ft. screens and two additional 4 × 10 ft. screens are utilized in the separation of the fibre from the adhering rock particles. A 100 horse-power motor is used in driving eight screens and a like number of fans. The resulting fibre is graded into three qualities: No. I spinning fibre; No. II and No. III, paper stock.

In addition to the mill, there is an office building 16 × 24 feet and two storeys high; blacksmith, machine, and carpenter shops; a boarding house 20 × 24 feet—accommodating 28 men; and another boarding house 30 × 42 feet with kitchen 16 × 16 feet attached—accommodating 26 men.

A railway siding, one mile long, to connect the plant with the main line of the Quebec Central railway, is now in course of construction. A storehouse 50 × 96 feet, located at the foot of the cyclone building, facilitates the handling of the finished product, as well as of all supplies for the mine; the car track of the railway siding being placed right in the middle of the same, the full length of the building.

The mine proper is located on the side of a hill, at a distance of about 500 feet from the milling plant, and consists, so far, of several open-cuts into the

[1] Since writing the above the milling plant has been changed, and at the same time the capacity increased to six cyclones.

hillside; no cable derricks being used in their operation. A very large amount of stripping has been done; and this, together with the development constantly going on, facilitates the study of the productive serpentine belt in that region: further particulars of which are given on page 66.

The main open-cut is 200 feet long, and 75 feet wide, with a rock face of 35 feet average. The exposed serpentine is of the East Broughton type, with this difference, however, that the fibre is, for the greater part, preserved in its original deposition; thus yielding a very satisfactory amount of crude. On the other hand—in comparison with the Thetford fibre, which exhibits peculiar dark shades when *in situ*—the asbestos is green and yellowish green in colour; the drawn out fibre, however, loses nothing of its silkiness and tensile strength.[1]

ASBESTOS LOCATIONS AND PROSPECTS.

There are quite a number of asbestos locations and prospects all through the asbestos region; on some of which enough work has been done to demonstrate the extent of the asbestos lodes and to warrant the expenditure for the erection of milling plants; while in others only small outcrops are in evidence, which must be further explored before any intelligent opinion can be expressed about them.

Commencing with the most northeasterly locations, and proceeding in a southwesterly direction, the most prominent locations are:—

Southwest half of Lot 13, Range III, Township of Broughton, County of Beauce—known as the 'Cliche' Property.

The northeasterly terminus of the productive serpentine belt is found on the westerly part of this property; no outcrops of value having been discovered farther than this. The belt crosses the property at a distance of 800 feet south of the main road, its width—on account of the overlying humus—could not be established, but the outcrops seem to indicate that this width is at least 75 feet. The principal work has been done on the portion close to the concession road, and consists of 5 pits: 2 of which are 80 feet apart, and are in asbestos ground of the slip fibre quality, measuring 20 × 10 feet and 45 × 6 feet, respectively, with a depth varying from 2 to 5 feet. The material on the dump shows a silky fibre in fine fissures of dark green, much twisted and shattered serpentine, and delivers —as a mill test has shown—a good commercial article. There is not enough work done on the property to justify the erection of a mill; the results in the excavations, however, encourage further development work. A siding from the property to the railway would cover a distance of about 3½ miles.

Northeast half of Lot 13, Range IV, Broughton—known as the Miller Mine.

This property was worked for crude some twelve years ago; the residue, owing to lack of treatment facilities, having been thrown on dump. A quantity of the latter was shipped to the Glasgow and Montreal mill at Black Lake, and tested;

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[1] Since writing the above, the capacity of the mill has been increased by the addition of 4 cyclones. The foundations for the new structure were commenced in November, 1909, and the whole plant is expected to be ready in June, 1910.

but although the material produced was of excellent quality, the excessive haulage charges were obviously against such a course. The principal work done consists of a pit 35 × 40 feet, and 20 feet deep, in a much fractured and fissured serpentine, containing slip fibre. This can be clearly perceived, especially on the western side of the pit, where the writer extracted, in a number of places, some excellent fibre, designated as No. I mill fibre. The other walls of the pit exhibit good milling material. On the northern wall the serpentine is more of a massive foliated structure, dipping to the north under an angle of about 65 degrees. Along the bedding planes asbestos occurs in the form of drawn out and to some extent compressed veins; they are found, on closer examination, to contain excellent fibre.

There are quite a number of smaller pits in the vicinity, all showing serpentine and fibrous rock, and indicating the extent of the belt to the south.

The dumps resulting from early operations in the main pit exhibit good mill material; and a mill test with 14,280 pounds of rock, taken from seven different places, and made in the mill of the Eastern Townships Asbestos Company, gave an extraction of 935 pounds of fibre, or 6·5 per cent. The extraction of No. I fibre was very high, and amounted to over 1·1 per cent—a result not often obtained in mines of this class.

Southwest half of Lot 13, Range IV, Broughton—known as the Roy Outcrops.

About 1,000 feet in a northeasterly direction from the concession road—IV-V, 3 small pits show the extension of the belt in a southwesterly direction, with the serpentine much shattered, due to atmospheric agencies: it appears talcose, and when exposed to the air takes a white tarnish. Some good slip fibre was seen in the cracks and interstices of the serpentine; a small percentage of it being brittle. The property is covered heavily with bushes, and no further investigations could be made.

Northeast half of Lot 13, Range V.

A good deal of prospecting and exploration has been done all over this property, with the result that, close to the southwest-northeast division line of the property, good slip fibre similar to the occurrence on the southeasterly part—now worked by the Boston Asbestos Company, was discovered in a small pit, close to the northern contact with the schist formation. The results so far obtained encourage further exploration and development work.

Northeast —(East) part of Lot 13, Range VII, Broughton.

This property is located between that of the Broughton Asbestos Fibre Company, to the southwest, and that of the Eastern Townships Asbestos Company, to the northeast. There is a large development of serpentine on this property; containing towards the southern boundary, and more especially to the southwest, a productive stretch of asbestos rock. Several small pits have been made in that portion, exhibiting milling material of good quality. This stretch is a continua-

tion of the productive asbestos rock now worked by the Broughton Asbestos Fibre Company, and also of the Montreal and Glasgow asbestos property to the south.

Lot 14, Range VII, Broughton.

This is the old Fraser property, which was worked some years ago. The serpentine has a slaty structure, and contains a number of small veins in one of the outcrops. Mining, however, has been confined to a peculiar vein which was developed on the southeast margin of the serpentine, close to the contact with the overlying schistose slates, which have at this place a dip to the southeast, at an angle of 65°.

The asbestos vein, which in places assumes a thickness of 10″ and 12″, follows a wall of soft talcose rock of soapstone, from 12″ to 14″ thick. The quality of the asbestos is excellent; but the veins are irregular, splitting up sometimes into fine strings disseminated through the serpentine, and at other places uniting and forming a continuous lead for about 100 feet. Some of the shorter fibre appears to be somewhat stiff and hard in texture. Wherever the vein assumed a large size, the fibre was soft and silky. Three shafts were sunk to a depth of 60, 62, and 78 feet, respectively, following the slope of the soapstone.

Southwest half of Lot 13, Range VII, known as the Tanguay Lot.

Close to the northeast, southwest range division line in the southeastern corner of the property, a number of pits, made several years ago, are in good asbestos ground, on the continuous belt of which the Broughton Asbestos Fibre Company is now working. The principal opening measures 40 × 28 feet, with a depth of 14 feet. The bottom of this pit, which was freed from water at the request of the writer, exhibits fine asbestos veins from ¼″ to ¾″ thick. The serpentine here is a massive rock; shows few signs of dislocation and fracture; and exhibits excellent asbestos—a silky fibre, which would yield a fine quality of 'crude.' The southern and eastern walls contain milling material in a crushed serpentine; while the western wall shows rich asbestos mill stuff, also yielding some 'crude.' The continuation of the productive belt towards the southwest, is shown in 15 pits, made over a length of 500 feet: all showing, more or less, the occurrence of the 'slip' fibre quality. There are, in the opinion of the writer, enough outcrops and pits on this property to warrant the erection of a milling plant.

Southwest half of Lot 13, Range VIII, Broughton, known as the 'Taschereau' property.

This property has since been acquired by the Montreal Asbestos Company.

In the centre of this property, several pits, over a distance of 125 feet, are made in a crushed and highly fissured serpentine; the fissures containing drawn out asbestos fibre—similar to the occurrences on the Tanguay property. At a distance of 1,250 feet along the division line of the property, in a southwesterly direction, the productive serpentine outcrops on a number of places. Eight pits

over a stretch of 550 feet towards the concession road are in fibrous serpentine of good milling quality. Plans for the erection of a 300 ton mill have been prepared. The Champlain Asbestos Company recently took over the property, and the installation of a complete mining and milling plant is contemplated in the near future.

Northwest half of Lot 13, Range IX, Broughton.

A considerable development of serpentine exists in the northeasterly extremity near the concession road VIII-IX; the width of the serpentine, with a few interruptions of country rock, being from 600 to 800 feet. No work of any kind has been done on this property; but several places have been found which bid fair to become likely producers of fibrous serpentine. This is a westerly continuation of the fibrous serpentine belt explored on the 'Taschereau' property; several good outcrops occur also along the concession road above named. Close to the northerly division line, between lots 12 and 13, and about 1,500 feet from the farmhouse of 'Lefebvre,' a small pit has been sunk in good fibrous serpentine; which, when dry, takes a white tarnish, and exhibits asbestos 'slip' fibre of good quality.

Lot 13, Range X, Broughton.

A hilly, well wooded ridge, crosses this property near the northeast boundary line, in a north-south direction. This ridge is composed, mostly, of a dark green highly fissured and at places schistose serpentine. Along the middle line of the lot several excavations were made on the steep slope of the mountain, and a fibrous serpentine, similar to that in East Broughton, was encountered. The extent of this fibrous rock appears to be considerable; but in the absence of any extended work on the property, figures as to size of the deposit can not be given.

East half of Lot 2, Range V, Thetford.

This property has since been acquired by the Berlin Asbestos Company, and a 4 cyclone plant is in course of construction.

A continuation of the productive asbestos range has been discovered on this lot, near the western division line. Three pits have been opened over a distance of 150 feet in the direction of the belt. They all exhibit greenish schistose serpentine, containing a white, silky asbestos 'slip' fibre, of good quality. In the easterly part of the lot, float asbestos has been found; indicating that the productive belt probably runs across the property. The development of serpentine on this property is probably extensive.

West half of Lot 2, Range V, Thetford.

Several excavations in the easterly part of the property exhibit a fibrous serpentine rock similar to the rock found on the next lot. The principal pit measures 8 × 10 feet, the bottom being in good fibrous material.

Lot 9, Range V, Thetford.

This property has since been acquired by the Beaudoin and Audette Asbestos Company, and a milling plant is in course of erection.

At the foot of a mountainous ridge, the serpentine outcrops on several places, and continues across the lot into the adjacent lot to the west—No. 10. The ground near the western boundary has been stripped over an area of 120 × 60 feet, and in one place a pit was sunk some 10 feet deep in a rich accumulation of asbestos veins. The fibre when freshly mined is of a greenish colour, and is somewhat different from that found in Thetford and Black Lake; but when worked up into fibre material appears to possess all the requisite qualities of a good commercial article.

The width of the productive serpentine between walls of country rock at the place above referred to, is about 100 feet. The length of the productive belt so far available is 250 feet; but it seems likely that additional productive ground may be discovered farther up the mountain.

Lot 10, Range V, Thetford.

Towards the easterly boundary in the direction of lot 9, a pit sunk in serpentine several feet deep exhibits a number of asbestos veins of excellent quality. No effort, however, has been made to determine the exact dimensions of the productive belt.

Lot 13, Range V, Thetford.

In the northerly part of this property, some development work has been done over an area 750 × 450 feet. This work consists of 8 trenches, one open-cut, and one pit, all located on the slope of a hilly ridge. The principal pit on the foot of the hill measures 85 × 25 feet—(depth on account of water not measurable.) The easterly side of the pit exhibits solid, massive serpentine; and over a space of 8 × 6 feet, and 18 feet long, good asbestos fibre, from $\frac{1}{8}''$ to $\frac{5}{8}''$ can be seen; which yields, besides some crude, good milling material. The dump close to this pit contains milling rock and waste; the latter, evidently, not having been kept apart.

The next important work is an open-cut, at a distance of 450 feet in an easterly direction from the pit above referred to. This cut has a length of 150 feet, is 6 feet at the entrance and 20 feet wide at the face of the cut, with a height of the latter of 15 feet. The serpentine is highly schistose; but contains some good 'slip' fibre and vein fibre—the latter predominating. The other trenches, located between this cut and the pit, serve to show the quality of the rock all along the slope of the hill; and it appears probable that a large deposit of good mill rock exists in this portion of the property.

Near *Kinnears Mills*, in the township of Leeds, several outcrops of serpentine have been found; but, so far, not much asbestos has been found in them. In the concession of Ste. Catherine on the road east of St. Sylvestre, some exploration work was done, but nothing of importance was found.

East of the railway, in Thetford, serpentine is seen on lots 10 and 11, range VII; on lots 14, 15, and 16, range VIII; lots 14, and 15, range IX; and on lots 5, 7, 9, and 10, range X, The rocks in all these places do not belong to the productive variety. In Adstock several outcrops of serpentine can be found; but the rock seems to lack asbestos, in paying quantities.

Lot 26, Range A, Coleraine.—Here, several large pits have been opened; but most of them are now under water. Indications of veins are quite numerous; but the rock as a whole appears to belong to the harder and drier variety, indicating an approach to the comparatively barren belt farther to the southeast. A number of short fibre veins occur in this area; but, generally, the output appears to be mostly milling material.

On *lot 25* a little work of an exploratory character has been done, and the rock here also appears to be of the harder quality.

Lot 27, Range A, Coleraine.—Several pits have been opened on a ridge of serpentine, which strikes in an eastern direction through the country. From one pit, measuring 75 feet long, 50 feet wide, and of shallow depth, about 1,000 tons of rock have been taken, which carried good fibre, short, and long, yielding a large percentage of milling material. The serpentine is conspicuous, on account of the occurrence of distinct seamy partings, generally of a whitish colour, most of which carry in the middle, very fine, silky, veins of asbestos.

In the bottom of one excavation a number of veins of very fine fibre were noticed, reaching in places, a thickness of 1½″ and 2″. There are a number of dikes of granite cutting the serpentine on this property, and it appears that in the vicinity of these dikes milling material, as a general rule, is plentiful. Many shallow openings, made all over the property on outcrops, show more or less the occurrence of the mineral.

Lot 32, Range A, Coleraine.—Some work of an exploratory character has been done on this lot, known as the Hayden property. The rock is a somewhat slaty serpentine of good character; but nowhere exhibits such massiveness as that of the Thetford areas. A good showing of veins was found, and the fibre appears to be of satisfactory quality.

Lot 23, Range B, Coleraine.—An excellent asbestos fibre, very similar to the beautiful Thetford variety, has been found in the northwesterly part of the property. Several pits along the line between lots 23 and 24, show quite a number of veins. However, not enough work has been done to determine the extent of the productive formation.

Lots 24 and 25, Range III, Ireland.—This property was at one time operated by King Bros., of Thetford. The elevation of the openings above lake level is about 800 feet.

The serpentine here, presents a roughly bedded appearance, with a dip to the northwest of 35° to 40°; in which the fibre was also found in zones, varying in length from ¼″ to 1″.

Some No. I and No. II 'crude' was obtained, and about 500 tons of asbestos were extracted and shipped to Coleraine station, a distance of five miles.

On lot 26, range III, there is a knoll of serpentine in which a number of veins of short fibre can be seen. Around the sides of Silver mountain, which is the prominent peak west of the lake, small veins were also disclosed, but the district as a whole appears to be unproductive, and no serious mining has been attempted.

Asbestos has been found on one of the islands of Nicolet lake, township of South Ham. The serpentine rock which forms the large island rises abruptly out of the water to the height of 70 feet, and is apparently seamed all through with fine asbestos veins. Quite a number of openings have been made, and they all show more or less that the serpentine contains likely asbestos rock of some value. The serpentine in some places has a steatitic feel and appearance, and some of the fibre apparently contains finely divided steatite. Picrolite is met with occasionally: this is generally brittle, and in some places emerges into mountain leather.

Lot 13, Range VI, township of Ham—Two miles from St. Adrien Village.

From the various outcrops, excavations, blastings, and other indications, it appears that the serpentine belt strikes through the lot in its southern part in an almost east-westerly direction, having a width approximately estimated at 125 feet. Its southerly boundary cannot be accurately established, on account of the heavy humus covering the formation; but the northerly contact can be well recognized in a hilly ridge striking east and west, and which is composed of the quartzose Cambrian rocks, having the same strike, and a steep southerly dip.

Most of the work on the property has been done on the southerly margin of the serpentine belt, and consists of 5 cuts, blastings, and excavations. The most southerly cut is a trench 5 feet wide, and about 20 feet long.

Cut No. II is located at a distance of 230 feet in a westerly direction from No. I, and consists of a rock cut in the hillside, 15 feet long, and 8 feet wide, with a face 15 feet high. Small veins $\frac{1}{8}''$, $\frac{1}{4}''$, and $\frac{3}{8}''$ thick, occur in irregular fashion through a dark green, hard serpentine. No crude was observed.

No. III constitutes a blasting on the side of the little hill, measuring 18 feet long, and 12 feet high. This rock face exposes a good showing of asbestos. Eight asbestos veins—three of which contained asbestos over $1\frac{1}{2}''$ long—occur almost parallel to each other, at intervals of from 2 to 3 feet, with a dip of about 45° to the southeast. Small veins measuring $\frac{1}{8}''$, $\frac{1}{4}''$, and $\frac{1}{2}''$, may be seen farther back of the rock face on the hillside for about 10 feet wide; but no asbestos could be seen beyond this. The quality of asbestos seems to be good; but when compared with the Thetford-Black Lake fibre has a glossy, almost vitreous aspect, when freshly broken, and the fibre, when drawn out, is of a white colour, lacking in silkiness. The serpentine is hard, and wherever the veins occur, black streaks accompany the same. It seems that in a more or less degree all these veins are confined to these darkened portions, that is, portions where a complete serpentinization has taken place.

Picrolite—a hard fibrous material, more or less brittle—may be seen in cracks or slickensided surfaces, and it seems that this product here is the direct result of the grinding movement of the rock mass.

No. IV is located at a distance of 100 feet, in northwesterly direction from No. III, and consists of a rock cut into the serpentine hill. Small veins intermixed at places with picrolite can be perceived in irregular conformation over the rock face. The mass constitutes milling material of satisfactory quality.

No. V is an excavation of the soil, several feet deep, at a distance of 420 feet in a northwesterly direction from No. IV. Serpentine was struck; but no asbestos was found. This excavation is located on lot 12, close to the division line between 12, and 13, range VI.

So far it has been shown that, the length of the serpentine belt is 815 feet, and its width at least 105 feet. The distance from the next railway station—Weedon, on the Quebec Central railway, is twenty miles. The profitable exploitation of this occurrence depends to a great extent on better transportation facilities.

Bras du Sud-Ouest.—The outcrops on the Chaudiere river at the Bras du Sud-Ouest, present also different features from those in Thetford and Black Lake. Here, in many places, the rock is a serpentine breccia; being only partially serpentinized as an alteration apparently from a pyroxenic mass. At several places where the serpentine is better displayed, small veins of an impure asbestos are seen; but these are of no economic importance. The associated rocks are black, rusty slates, with bands of hard grits, and slate conglomerate. Diorite and granite are found in the immediate vicinity.

Des Plantes River.—Some asbestos has been found on the Des Plantes river, on the north side of the Chaudiére, half a mile from the latter. Here, black and grey altered slates and quartzites are in contact with a dark, slaty serpentine, which is cut by dikes of a white granite. Some small veins of asbestos can be seen, but as no further work has been done on these outcrops, no definite opinion can be expressed.

Some encouraging features have been noticed on a property higher up the river, close to High Falls. Here, an open-cut was made in a knoll of serpentine, and quite a number of veins, though small, were encountered. The serpentine here has a different character from that met with in the property above described, in being compact, massive, and in showing vein fibre, instead of the slip fibre variety. More work must be done, however, before a definite estimate of the extent of the deposit can be given.

Near Brompton Lake.—On lot 26, and half of lot 25, range IX, Brompton—comprising in all 350 acres, some work was done, in 1889, by the Brompton Asbestos Company, a Montreal corporation. It was reported that some of the fibre is of excellent quality. The rock is associated with great masses of diorite and slate containing white garnets and differs in many points from that of Thetford and Black Lake. It is harder, and darker coloured; and in places becomes talcose in appearance. The veins are often brittle, and without the fibrous character. The area, as a whole, has not been productive to any great extent.

The Eastman Locations.—A good deal of exploratory work was done in the years 1906, 1907, and 1908, around Eastman—a station on the Canadian Pacific railway, twenty-eight miles from Sherbrooke, and seventy-eight miles from Montreal. The serpentine belt south of this locality was the object of special attention, with the result that some promising outcrops were located.

Lot 2, Range XI, Bolton.

Two bands of a group of parallel asbestos stringers ⅛″ up to ⅜″ thick, occur in a dark green massive serpentine on the side of a precipitous mountain, not far from Orford lake. This occurrence was opened up for over 15 feet by some blasting, and a small open-cut. A similar occurrence was noticed at a distance of 1,000 feet in a northeasterly direction; but there was not enough work done to study the extent of the deposit.

Quite a lot of work has been done on different parts of the property. The principal opening is in the centre of the lot on the side of a bluff, 40 feet wide, and from 6 to 8 feet high. The serpentine here is very hard, and siliceous; but at one place some narrow veins of asbestos were noticed; and parts of the dumps exhibit some good milling material.

At a distance of 450 feet from this opening, and in a southerly direction, a pit 25 × 10 feet and several feet deep is in dark green, massive serpentine, containing some irregular small veins of asbestos.

All the other places show similar conditions, and it appears that some of the asbestos partakes of the brittle character of the enclosing serpentine.

Lot 9, Range VII, Bolton—Called the Parker Lot.

Some work has been done on this lot, along a knoll of serpentine which is flanked to the east by hard siliceous country rock. An open-cut has been made along the side of the hill for a length of about 160 feet, and almost parallel to the contact with the country formation. This quarry exhibits a much fissured fibrous serpentine; asbestos stringers are frequent, and it seems possible that milling material in sufficient quantities may be encountered to keep a milling plant running.

The westerly extension of the serpentine is very likely to be found in the flat to the west. The northerly extension of the serpentine belt can be seen in the denuded portions of a hilly range 250 feet distant, and here, on the slope of a little hill, small veins of asbestos have been found. Further development work should be done on this deposit to determine the actual value of the occurrence.

The foundations for the milling plant have already been laid: close to a little lake at a distance of about 600 feet in a southerly direction from the mine.

This property has been acquired by the Brome County Asbestos Development Company.

Lot 10, Range VII—known as the Benoit Lot.

The serpentine formation outcrops west of Trousers lake in the shape of several parallel, rocky, and steep ranges. The one most easterly, strikes in a north-

easterly direction through the country, and is approximately 400 feet long, 200 feet wide, and 100 feet high. Both the easterly and westerly sides of this ridge are steep and rocky, and the serpentine is well exposed. On the western side of this ridge is an adit 15 feet high, 12 feet wide, and 20 feet deep. The serpentine is of a dark green and grey colour; is harder than the ordinary run of serpentine; and contains, occasionally, some small veins of asbestos. The productive character of this rock has not, as yet, been established.

This property is now owned by the Brome County Asbestos Development Company.

Among the other asbestos outcrops in the vicinity may be mentioned, specially, the John Carpenter deposit on cadastral lot 948, north of Trousers lake, about three-fourths of a mile from the main road leading to St. Etienne, on the side of a low ridge with northeasterly strike. About 80 feet of blasting has been done all along the brow of the hill, in a dark green serpentine, which on the surface is in a crushed and foliated condition; but which becomes massive at a depth of a few feet. The exposed rock exhibits asbestos in a number of veins measuring from $\frac{1}{16}''$ to $\frac{3}{8}''$ thick. The dumps from the blasting operations showed a fair percentage of asbestos fibre all through. The asbestos, though yielding some silky fibre, is to some extent brittle, and breaks up when subjected to mechanical force.

Asbestos has been discovered on cadastral lot No. 967, belonging to E. T. Esty; also on lots 744, 768, 967, and 971, belonging to the Peasley family. These lots are located west of Lake Nick, near Bolton Centre.

The lots are occupied by a high, hilly, comparatively well wooded, range of serpentine, on which prospecting work has disclosed some ten occurrences of asbestos fibre. The serpentine is massive, and of a very dark, almost black-green colour, and shows no signs of displacements and contortions. In some of the outcrops—especially on lot 969—$\frac{1}{4}''$ and $\frac{1}{2}''$ veins could be seen on the freshly blasted rock face; some of the fibre breaking up when subjected to force.

The Mansonville Locations.

Near Mansonville in the township of Potton, not far from the Vermont boundary line, several properties were examined; but with few exceptions the veins were not of sufficient magnitude to encourage actual development work. On one property about three-fourths of a mile from the village, an extensive hilly ridge of serpentine occurs, with asbestos veins $\frac{1}{4}''$ and $\frac{3}{8}''$ thick, distributed through the rock-mass. Most of these veins were embedded in a bright green hornblende rock, forming, so to speak, seamy partings in the serpentine from $\frac{1}{2}''$ to $\frac{3}{4}''$ thick.

The Richmond Locations.

Some prospecting has been done over the serpentine range located in the immediate vicinity of the flag station—Coris—on the main line between Montreal and Sherbrooke, on the Grand Trunk railway, four miles east of the town of

Richmond, and eighty miles from Montreal. The area prospected covers 600 acres, and more particularly the southwest half of lot 5, range XIV; the southwest half of lot 6, range XIV, and the whole of lots 5 and 6, range XV, of the township of Cleveland, county of Richmond.

Blasting has been done on several places along the eastern slope of the mountainous range: on lot 6, on ranges XIV and XV. The most westerly deposit is located at a distance of about 1,500 feet in a northeasterly direction from the railway track near the foot of the hill. The opening was blasted along the hillside in serpentine: the exposed rock face being 40 feet wide, and from 12 to 15 feet high. Asbestos veins occur along the rock face over a width of 3 feet: they are all parallel to each other, and are from $\frac{1}{8}''$ to $\frac{3}{8}''$ thick. This whole accumulation has the appearance of a lode, with distinct selvage planes striking northeast 70°, having a steep dip towards the north. Part of this asbestos serpentine lode has been mined, and the dumps near by contain some milling material.

Another opening was made near the division line, on lot 6, between ranges XIV and XV; it was blasted along the hillside, 50 feet wide, and from 10 to 15 feet high; and quite a number of asbestos veins were laid open—most of them from $\frac{1}{8}''$ to $\frac{3}{8}''$ thick. The property being located close to the main line of the Grand Trunk railway, possesses excellent transportation facilities.

Shipton.

Lot 12, Range V, Shipton.—In the northerly part of the lot, serpentine occurs; flanked by granite towards the west. This property was worked some fifteen years ago. Recently, operations were resumed, and a pit—measuring 20 × 25 feet, and 5 feet deep, was worked. Quite a number of asbestos veins and stringers could be seen in a dark green serpentine; the extent of the latter being evidently large.

Lot 9, Range VIII, Shipton.—Not far from the 'pinnacle,' a stretch of serpentine has been explored, with the result that quite a number of small asbestos veins, occurring at intervals through the rock, were located.

Similar occurrences to those reported in the township of Shipton may be seen on lot 12, range V; also on lots 9 and 10, range X, in the same township; some of them look quite promising, but it is recommended that more work should be done.

Tingwick.

Lots 20 and 21, Range VI.—A serpentine belt crosses these properties close to the centre; and considerable development work has been done on No. 20, near the boundary line between the lots. All the pits at the time of examination were full of water; but the writer was able to see from several strippings that the serpentine is interwoven with asbestos veins $\frac{1}{4}''$ and $\frac{1}{2}''$ thick. This was specially noticeable on strippings from 10 to 20 feet wide around a pit measuring 40 × 50 feet. At another pit, at a distance of 150 feet in a westerly direction, similar conditions were noticed. This property is equipped with a small cyclone

mill; with a power house containing 2 boilers and steam engines; 1 saw mill; and a sleeping and cooking house. At present, operations are suspended.

This serpentine crosses also lot 21, and can be closely studied near the creek which traverses it. It shows in different sections—especially in a little pit close to the creek—quite a considerable accumulation of asbestos veins, which, although the majority are small, would provide material for a mill of considerable magnitude. The writer believes that two cuts on both sides of the creek into the serpentine would open up the property in a comparatively short time, and demonstrate its value.

These two asbestos locations are nine miles from the next railway station—Danville.

Lake Chibougamau.

On Asbestus island a variety of serpentine occurs similar to that of Black Lake; but whether it contains enough asbestos to warrant exploitation on a large scale is still an open question. Mr. Dulieux, M.E., Montreal, who made a visit to the Chibougamau region, expresses himself as follows on the subject[1]:—

> 'Numerous attempts have been made to discover asbestos, for nearly everywhere in the serpentine are to be found small quantities of fibrous matter in the fissures. Except on the asbestos island, situated in the west part of Mackenzie bay, the prospectors have nowhere shown the existence of asbestos in marketable quantities.
>
> 'Asbestus island in its central portion consists of a green serpentine, impure and highly magnetic. Veins of a purer serpentine and lighter in colour, accompanied by veins of garnetiferous pyroxene, are found on an elevation on the highest part of the island. It is at this level, in close proximity to the veins of pyroxene, that the finest asbestos on the island is to be found. Certain pieces of serpentine in close contact with the pyroxene rock contain a high percentage of silky asbestos in little parallel veins. Unfortunately this proportion of asbestos diminishes very quickly in going away from the contact.
>
> 'Open-cuts were made on the south slope of the island into the impure serpentine. At the time of my visit the cuts showed only a few thin veins of asbestos as well as veins of picrolite (hard asbestos). On the dump, however, I could see blocks of serpentine thrown out during former operations, among which were fragments showing some fine veins of half to three-quarters of an inch in width.'

Mr. Dulieux's conclusions are:—

> 'Up to this date asbestos is not found in marketable quantities except on the asbestos island in Mackenzie bay.'

It may be mentioned that the distance of this mineral zone from Lake St. John is 170 miles. It is understood that a beginning will be made with the construction of a railway to that country during the summer of 1910.

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[1] The 'Chibougamau District'; paper read before the Annual Meeting of the Canadian Mining Institute, March, 1909.

CHAPTER VII.

ASBESTOS IN FOREIGN COUNTRIES.

United States.

The production of asbestos in the United States is about 1 per cent of the Canadian, and becomes wholly unimportant when we consider that this 1 percentage consists only of a low grade material; a grade which is not produced in any of the Canadian mines. The total output of the United States is composed of the variety which is generally known, mineralogically, under the name of 'amphibole': the average price of which, in 1907, was only $18 per ton; whereas the average price realized for the Canadian product, in the same year, was about $40 per ton.

The United States, in 1906, produced 1,695 short tons of asbestos; but in 1907 the output decreased to 653 tons—a decline of over 61 per cent. The value of the asbestos (in part estimated), in 1907, was $11,899, and in 1908, $19,624.

Nearly all of the output came from the Sall Mountain, and Hollywood mines in Georgia and Vermont: which were the only States that furnished asbestos for the market in 1908; and nearly half of the quantity produced was exported.

The imports in 1907 were:—

Unmanufactured, $1,104,109, against $1,010,454 in 1906; manufactured, $200,371, against $65,716 in 1906. Total, $1,316,379 in 1907, against $1,076,170 in 1906.

During the fiscal year ending June 30, 1908, there were 50,503 tons of unmanufactured asbestos imported from Canada into the United States. This would seem to show that approximately 51 per cent (valued at about $1,314,337) of the total production of Canada, in 1908, went to the United States. During the same period the total importations of asbestos by that country, from Germany, Italy, and the United Kingdom—the only other countries from which asbestos was obtained—amounted to less than $2,000. In 1907, the United States took 73 per cent of the total Canadian production: the falling off in 1908 being due to the great financial depression which was felt in all classes of industry.

WYOMING.

Asbestos has been known to exist on Casper mountain, and in the adjacent ranges in Natrona county, in the State of Wyoming, for many years; but no commercial use was made of these deposits until the year 1908.

The North American Asbestos Company has secured 1,000 acres of land on Casper mountain—seven miles south of the town of Casper, and has been pushing development work there during the past season. The main tunnel has shown a mass of asbestos rock 20 feet wide, and the full extent of the deposit is not yet

determined. The formation is serpentine, in granite and schist, the bands ranging up to 200 feet wide, with the asbestos showing for some two miles along their course.

The Wyoming Construction Asbestos Company has property on Casper mountain, and on Smith creek, where their principal quarries will be located. The asbestos has been opened there by cuts and strippings, and shows a formation similar to the Casper Mountain deposits, the serpentine stripped showing a width of about 300 feet.

Mr. T. S. Diller[1] reports on the Wyoming asbestos deposits as follows:—

> 'There are two districts of asbestos bearing rocks in the Casper region—one on Casper mountain, nine miles directly south of Casper, embracing approximately an area equal to three sections, and the other half as large on Smith creek, 30 miles southeast of Casper.
>
> 'In both districts the asbestos occurs in serpentine almost wholly in the form of cross fibre veins. It is chiefly chrysotile, but the fact that some of it has a considerable degree of brittleness suggests that it may be amphibole. This is true especially of the small quantity of slip fibre which occurs minute parallel veins of asbestos, which range from a mere fibre to ¼", in thickness. The larger ones are generally jointed or banded parallel to the vein walls, thus parting the fibre into shorter lengths.
>
> 'The most common type of asbestos bearing rock is banded by numerous minute parallel veins of asbestos, which range from a mere fibre to ¼", rarely ½", in thickness. These cross-fibre veins are so abundant in places that they form from 20 to 50 per cent of the banded rock. The belts of banded rock range from a foot to several feet in thickness.
>
> 'Much of the serpentine is covered by soil. Weathering is deep and impairs the asbestos near the surface. The best exposures of fibre are in some of the deeper shafts. This does not mean that the quantity of asbestos increases with the depth, but to some extent the quality may improve.
>
> 'The highest grades, Nos. 1 and 2 crude, are practically absent from most of the area already prospected, but there are locally considerable masses of rock suitable for milling. They constitute, however, a small percentage of the whole body of the serpentine.
>
> 'The serpentine is cut by the granite of the same region, and although the intrusion of the granite may be regarded as resulting in the formation of much of the asbestos, yet it must not be forgotten that the granite limits the serpentine.'

NORTH CAROLINA.

A discovery of asbestos is reported at Taylorsville near the Tredell county line, North Carolina: the extent of which is not yet known.

In Yancey county, of the same State, about eight miles west of Spruce Pine, on the road to Burnsville, near the junction of the North and the South Toe rivers, chrysotile-asbestos has been found in some quantity on a hill which rises about 300 feet above the surrounding country. The fibre is of good quality: and although little work has been done on the deposit, the serpentine has been proved to contain asbestos for a distance of 250 feet in length, by 50 to 75 feet in width. A tunnel running about 35 feet below the outcrop, encountered the same chrysotile-asbestos at that depth.

[1] Extract of Mineral Resources of United States for 1907.

ARIZONA.

In 1903, a deposit of chrysotile-asbestos was found in Arizona, at the head of Pinto creek, twenty-three miles west of Globe, Gila county. This deposit was located by Mr. M. L. Shackelford, of Prescott, Arizona. The asbestos bearing serpentine can be traced for over three miles, and the asbestos deposits are as a rule found on the contact with the country rock. Samples of this asbestos have been examined, and were found to be of good quality; the fibres varying from a fraction of an inch to 2″ and 3″ in length. The only work done on this deposit up to the present time was one year's assessment work; so that there is not very much known, as yet, regarding the extent of the deposit, or the percentage of asbestos that can be obtained in mining.

Within the last few years deposits have been found on the north side of the Grand Cañon, twenty-five miles northwest of Grand Cañon station, in the vicinity of Bass Ferry. The Grand Cañon at this point is 4,500 feet deep, and the asbestos occurs about 450 feet above the bottom.

Mr. T. S. Diller[1] reports on these occurrences as follows:—

'The Grand cañon exposes an excellent section of the Carboniferous, Cambrian, Algonkian, and Archæan rocks. The Algonkian is markedly unconformable with the overlying Cambrian as well as the underlying Archæan, and forms a wedge-shaped mass with its edge along the cañon near its bottom, and thickening rapidly to the north. The asbestos occurs in the basal portion of the Algonkian. This is made up, first, of a few feet of siliceous conglomerate, overlaid by about 50 feet of variously coloured fine shaly beds, locally calcareous or serpentinous. Then follows 15 feet of whitish limestone containing layers and nodules of serpentine with more or less asbestos.

'Above the asbestos limestone comes a heavy layer of compact diabase about 200 feet thick, and above the diabase is a bed of limestone and shaly rocks similar to those immediately below the diabase. A little asbestos may be seen in the limestone above the diabase, but it is much more abundant in the lower limestone.

'The asbestos bearing limestone below the diabase varies considerably from place to place, but for the most part, has approximately the following section: compact limestone, 1·8 feet, serpentine with veins of asbestos, 1·2 feet, banded whitish limestone, 12 feet.

'The upper and lower portions of the limestone may contain some bands and nodules of serpentine, but they are not as persistent as the intermediate layer of serpentine, in which is found nearly all the asbestos. It occurs in cross-fibre veins which lie parallel to the bedding in the limestone.

'The cross-fibre veins range from a small fraction of an inch to about 3″ in width, and are remarkable for their golden yellow colour, as well as for the tensile strength of the fibre.

'The overlying diabase looks unaltered, and at its contact with the limestone is distinct, except where the top of the limestone is serpentine.

'The facts observed in the field appear to indicate that the serpentine which includes the asbestos (chrysotile) is derived from some mineral in the limestone and not from the diabase. Conclusive evidence concerning its derivation cannot be obtained until the rocks are examined in the labora-

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[1] Ibid.

tory. If the suggested conclusion proves to be true, the Grand Cañon asbestos affords a type quite different in origin from any yet found at other localities in the United States.

'Four asbestos claims have been taken up, one on the upper and three on the lower limestone, along which the thin belt of included asbestos bearing serpentine has been prospected in a number of shallow open-cuts for over half a mile. The continuity of the narrow asbestos belt is very irregular, and disappears locally, but it is abundant enough in places to suggest the probability that Nos. 1 and 2 crude fibre, carefully selected from the veins, may be mined to a small extent at a profit. It does not seem at all probable, however, considering the limited quantity, location, and distribution of the deposit, that it would pay the mill.'

CALIFORNIA.

Prospecting continues in the large mass of serpentine cut by the cañon of American river, two miles east of Towle, on the Southern Pacific railway, in Placer county, Cal. The cañon is more than 1,000 feet deep, and affords excellent exposures. Several tunnels have been run into the steep slope to the depth of 100 feet, or more. Small veins of short, cross fibre, and irregular sheets of strong flexible slip fibre have been discovered; but they are too sparsely distributed to be mined with profit for the fibre alone.

Several deposits have been opened up lately near Green Valley, not far from Alta. It is reported that Eastern capital is interested, and that the mine will be thoroughly developed.

TEXAS.

According to Mr. T. S. Diller[1] a dull, greenish amphibole asbestos—possibly actinolite—found in Texas, is mixed with other ingredients to make asbestos paint.

VIRGINIA.

Bedford county, Virginia, has been reported as producing asbestos for a number of years; but did not produce any in 1907. The quarries—located in Bedford and Franklin counties—are now inactive and the mill at Bedford City, for fiberizing material, is closed.

The Bedford asbestos quarries are on the Hubbard farms, twelve miles south of Bedford City, and are spread over two areas: one, about 2 acres, and the other, 5 acres.

The asbestos rock is of two types: one—like that of Sall mountain, Ga.—is essentially fibrous, and amphibole; while the other is peridotite, composed chiefly of a granular mineral which appears to be olivine, with numerous acidular crystals, and fibrous bundles of anthophyllite.

In the amphibolite the fibres are arranged in groups or bundles lying in all directions—mass fibre similar to that of the Sall Mountain mines of Georgia.

[1] Extracts from Report of Mr. T. S. Diller, United States Mineral Resources for 1907.

Only a small deposit of it occurs in the Bedford region. In the northern part of the area, a vertical dike-like mass of this amphibolite, 5 feet wide with a strike north 80° west, lies parallel to the schistosity between masses of pyroxene-hornblende schist. It seems most probable that the amphibolite, composed of mass fibre asbestos, at Bedford, Virginia, and Sall mountain, Georgia, is derived from pyroxenite; but the evidence favouring this view cannot be considered in this paper.

The peridotite type of asbestos rock is cut by a few small veins of cross fibre anthophyllite, from $\frac{1}{8}''$ to $\frac{3}{4}''$ in length. The fibre is flexible, and somewhat elastic; but it has numerous cross fractures, and unlike chrysotile, is short and brittle.

This rock is cut also by occasional planes of shearing, along which there have been developed vein-like masses of slip fibre, which lie parallel to the plane of slipping. These are the masses which attract the attention of the prospectors, and are the parts that have been mined. They are locally 18″ thick, and have a length along the strike of about 30 feet. How far they have been followed in depth could not be learned, and the holes were filled with water at the time of the writer's visit. These masses of slip fibre are very irregular, and, as far as yet known, too small to furnish a reliable basis of mining operations.

Franklin County.—A small quantity (40 tons) of slip fibre has been mined near Rocky mound, in Franklin county. The vein, with strike south 50° east, and steep dip to the northeast, lies parallel to the schistose structure of the enclosing amphibolite. It has been mined out in a shaft nearly 40 feet in depth. The amphibolite is much altered. Its principal constituent is acidular crystals, and fibrous bundles of a colourless mineral with cleavage like amphibolite. It looks very like anthophyllite; but has inclined extinction, hence is probably tremolite.

All these asbestos bearing rocks of the Rocky Mountain region are practically amphibolite. Locally, it contains some olivine, and is much altered to chlorite and serpentine. In none of the outcrops prospected does the amphibolite contain a sufficiently large percentage of asbestos to indicate clearly the probability of profitable mining.

There are two belts of amphibolite lying between masses of mica schist which has a remarkably regular cleavage; so that it can be split into thin slabs, yards in extent, and has been quarried for curbing and flagging. The schistose structure is not nearly so prominent in the amphibolite as in the neighbouring mica schists.

VERMONT.

There is a large development of serpentine on Belvedere mountain, in the extreme western portion of Lowell. Several discoveries of short asbestos fibre were made in 1893, and were regarded as sufficiently encouraging to warrant the erection of a milling plant on the southeastern slope of Mount Belvedere; but the venture was not successful. According to Prof. Kemp[1], the asbestos occurs in

[1] United States Mineral Resources, 1900, page 862.

two distinct and contrasted varieties. In one case it forms veins which ramify in every direction through the serpentine. The asbestos fibres are perpendicular, or at a high angle to the walls, and vary from a maximum length, of $\frac{3}{4}''$—as at present exposed—down to not more than $\frac{1}{16}''$. The variety is similar in all respects to the Canadian product; but it is only met in the prospects owned by Mr. Tucker, at Tuckers mill, and near Lowell. The second variety of asbestos is 'slip' fibre; because it occurs on the slickensided surface common to the exposure of serpentine, which is characteristic all the world over. These fibres form layers of varying thickness, seldom more than $\frac{1}{4}''$; but inasmuch as they run parallel to the slickensided surfaces, they may, themselves, be of several lengths, from a fraction of an inch to 3″ or 4″. The fibre is coarser than that of the vein, hence does not furnish so good a grain; it is, however, more abundant.

A milling plant has recently been erected by the Lowell Lumber and Asbestos Company—with Mr. William Gallagher as president—on the southern slope of Belvedere mountain, on what was formerly known as the Tucker property, and since the autumn of 1909, has been in constant operation. The mine is located at an elevation of 1,500 feet above sea-level, and about 500 feet over the surrounding country. The productive belt is about 300 feet wide. The serpentine is of greenish, mottled colour, and in its outward appearance is entirely different from that of Black Lake and Thetford. It carries asbestos veins up to 1″ thick; but the fibre, as a rule, is divided in the middle, parallel to the walls, by a seamy parting of serpentine, sometimes containing fine grains of magnetite, and chrome iron ore. At the time of the writer's visit, in March, 1910, the main working pit, which represents an open-cut, was 75 feet wide, with a rock face of 40 feet. These veins ramify through the rock in irregular fashion, and some rich rock is occasionally met with. About one-half of the serpentine goes to the dump, and the balance is a milling material of good quality. No 'crude' is obtained. The mill is capable of treating about 200 tons per day, and the fibre produced compares favourably with that found in Canadian mines. The absence of an electric power plant, and the distance of twelve miles from the next railway station, Johnson—on a branch of the 'Boston-Maine'—is somewhat of a handicap to the economical exploitation of the deposits; but plans are under consideration for the construction of a hydro-electric power plant, on a tributary of the Missisquoi river, three miles distant; also for the construction of a branch railway line.

The mine produces between 15 and 20 tons of fibre per day.

GEORGIA.

The principal part of the asbestos production in the United States comes from the Sall Mountain quarry in White county: owned by the Sall Mountain Asbestos Company. Mining was first commenced in 1894; and subsequently a small mill was built producing about 10 tons a day.

Mr. T. S. Diller[1] reports on these and other occurrences as follows:—

[1] Ibid.

'The asbestos mined at Sall mountain is mass fibre. It is of an entirely different type from the most part of that mined elsewhere in the United States or Canada. The rock is amphibolite, its whole mass is made up of groups or bundles of more or less radial, fibrous asbestos, which ranges in length from 1¼" down to a small fraction of an inch.

'These radial fibres tend to form spherical bunches, but with interferent crystallization these bodies are only imperfectly developed, and in most cases the radial structure is lost in an irregular accumulation of fibrous sheaves or bunches running in all directions and giving the rock an aspect of coarse granular crystallization. None of the fibrous amphibolite masses are schistose, though near the edge they sometimes pass into talc schist with definite fissile structure.

'The fibrous amphibolite, composed of anthophyllite where best developed and freshest in the Sall Mountain mines, is greyish white, and composed so largely of asbestos fibre that according to the estimate of the superintendent, S. B. Logan, considerably over 90 per cent of the original rock is realized as fibre.

'Besides a little talc and carbonate of lime, the best rock contains numerous small grains of pyrite and magnetite, which, upon alteration stain the fibre brown with iron oxide, and in the course of time the whole mass softens without losing its fibrous structure. The tensile strength of the fibre is reduced in this change, but sufficient strength still remains to make the fibre useful as a binder when mixed with other material.

'The occurrence and persistence of these masses of fibrous amphibolite is a matter of prime importance, and the mines at Sall mountain throw considerable light upon the subject. Within an area a little more than one-eighth mile square, there are six separate masses, each one roughly elliptical in shape. Three of these, embracing the most important, are in line, with their longer axes approximately parallel and running north 80° east. They are all embedded in gneiss which is well exposed at many points in the mine, and in places appears to be cut by the amphibolite as an eruptive.

'The largest mass of amphibolite (the original discovery) had a length of about 75 feet, and a width, near the middle, of 50 feet. It is nearly mined out at depth of 50 feet, and unless a small remnant at the southwest corner shows connexion downward, as seems improbable from the course of the walls exposed, the mass is completely cut off below by the gneiss.

'The two smallest masses have been completely removed, showing a continuous exposure of the decomposed gneissoid rocks beneath. The relations of the three remaining amphibolite bodies to the gneiss have not been fully determined. The quality of the remaining bodies is inferior to that of the largest body, but they will supply the mill for some years to come.

'*Cleveland and Soque.*—Near Cleveland, five miles southwest of Sall mountain, there is a group of comparatively small, undeveloped masses of fibrous amphibolite, like that of Sall mountain. These are in a belt, trending about 41° east, almost directly towards the Sall Mountain locality. They are surrounded by gneiss. The Sall Mountain Company owns this property and hauls the material to the Sall Mountain mill.

'Near Soque, seven miles northeast of Sall mountain, are small areas of exposed amphibolite with short fibre. The amphibolite is here associated in the same ledge with a fresh rock that is composed chiefly of a mineral which appears to be pyroxene or olivine, with numerous acidular crystals and fibrous bundles of orthorhombic amphibolite, probably anthophyllite.

'The rocks, like those of Bedford and Rocky Mount, Va., and unlike those of Sall mountain, and Cleveland, Ga., have been sheared, and locally, on the planes of shearing, contain considerable slip fibre, which attracted the attention of the prospectors. The strike of the amphibolite belt, as well as of the plane of shearing, is approximately north 70° west. Several other localities of the same material occur farther northeast, in Habersham and Rabun counties. One of them, the Miller property, was worked many years ago, but as far as known they are not of economic importance.

'*Hollywood mine.*—A small production of asbestos, in 1907, was reported, by the National Asbestos Company, from a mine near Hollywood, in Habersham county, Ga., where a new mill was operated for a few months and then closed. The rock is firm and comparatively fresh. The least altered portion is composed of coarse granular pyroxene and acidular fibrous amphibolite (asbestos), with much talc, chlorite, and magnetite.'

Philippine Islands.

In the *Philippine Journal of Science,* also in the *Far Eastern Review* for June, 1907, Warren D. Smith gives an account of prospects of asbestos in Ilocos Norte, in the northern part of the island of Luzon. There has been no production, nor, indeed, much definite prospecting. It is certain, however, that there is a large mass of pyroxenite and serpentine in that region; and it contains locally some asbestos, part of which is fibrous serpentine; but most of it is of the amphibole type. It appears that the asbestos is sufficiently abundant to justify thorough prospecting with a view to determining its workability.

The asbestos is of two varieties, the 'parellel' and the 'cross' fibre, with the former predominating. The 'cross' fibre variety—probably 'chrysotile'—has not been found so far in any quantities; but the other quality, according to Mr. Smith, is found in several places, and consists largely of the minerals 'anthophyllite' and 'tremolite,' both belonging to the 'amphibole' group.

Newfoundland.

In the beginning of the nineties, last century, some excitement amongst asbestos men was caused by the alleged discovery of fine asbestos in large quantities in the serpentines on the west coast, chiefly in the vicinity of Port au Port bay. The rocks with which asbestos bearing serpentines are most commonly associated in the Province of Quebec, form a considerable belt along the west coast of Newfoundland. In these rocks, which consist of slates, sandstones, diorites, and tremolites, are also to be seen large masses of serpentine similar to that at Thetford. Here and there, also, are huge mountains of magnesian limestone, and in the region of Grand lake, and other isolated sections, are found carboniferous basins. Still, this entire area, extending about 100 miles north and south, and the entire width of the island east and west, can be safely called a serpentine country; and contains—according to Mr. Jas. P. Howley's estimate—5,097 square miles of serpentine rocks. Mr. C. E. Willis[1], of Halifax, and Mr. Robert Jones,[2] of London, England, have spent considerable time in the investi-

[1] Canadian Mining Review, 1893, page 207.
[2] 'Asbestos,' by R. Jones, 1897, page 55.

gation of these asbestos deposits, and a brief account, therefore, ot their character may be opportune.

The serpentines, with the granulite dikes which everywhere intersect the country rock, contain vast deposits of minerals, and are, to-day, with the exception of the immediate coast line, nearly virgin fields for the prospector and miner.

The existence of asbestos in this great belt of serpentine has long been known, and several well known geologists in their writings have predicted that it would be discovered in quantities sufficiently large to be of economic value. On the eastern coast of Port au Port bay, rising out of the sea to a nearly vertical height of 1,800 feet, is a mountain known as Bluff Head. This mountain determines the southern boundary of the serpentines. For many miles north, the coast line is precipitous and lofty, culminating at Cape Gregory in a bluff nearly 2,500 feet high.

At Bluff Head, and extending for about one mile north, the beach is composed of conglomerate, very hard, and highly polished on the surface by the action of the surf which breaks upon it. The beach is strewn with boulders of all sizes, which have fallen down from the cliffs, and nearly all of them contain seams of asbestos, while the conglomerate of the beach itself is filled with it. It was here that the asbestos first attracted much notice.

Long known to the fishermen of the neighbourhood as 'cotton rock,' it came to the knowledge of the Honourable Daniel Cleary of St. Johns, who equipped a small expedition to do some prospecting in the neighbourhood.

A great many claims were at once secured, and in a short time some thirty square miles were taken up by prospectors and speculators. Development work was started; but it appears that no operations on a large scale were conducted on any of the properties. Most of the development work was done by the Halifax Asbestos Company. The work extended for many hundred feet along a gulch through the surface drift. In each opening, small veins of asbestos were found; while the surface drift, which varied from 3 to 12 feet in depth, was in most cases saturated with loose fibre, entirely free from the matrix; the result of the decomposition of the serpentine through the action of frost and weather.

The fibre is mostly short; specimens, however, of 2″ in length, have occasionally been found. It is claimed that the peculiar green tinge of the asbestos; the colour and composition of the serpentine; the granulite dikes, and many other geological peculiarities go to prove the remarkable similarity of this region to the asbestos region of Quebec.

However, as already stated, nothing beyond work of an exploratory character has been undertaken on any of the properties, and on account of the remoteness of the districts, and the sporadic and erratic occurrence of the asbestos, there is no likelihood that Newfoundland will ever become 'Quebec's greatest rival ere long,' as an enthusiast puts it.

Russia and Siberia.

The Russian (Ural) asbestos is becoming in a small way a competitor with the Canadian asbestos; but only in the spinning quality. The freight charges

From Becker and Haag, Berlin. View of Russian asbestos quarry.

from the Russian mines to the seaboard are so high, namely, from \$30 to \$35 per ton, that the lower grades cannot be shipped economically, and, therefore, do not compete seriously with the Canadian fibre. The Russian lower grades are used, like the Thetford mill fibre, for the manufacture of shingles, and are absorbed principally in home consumption. These lower grades are cleaned by a certain washing process, of which little is known, but it is a noteworthy fact that the Russian asbestos is remarkably free from rock matter. Russian asbestos is mostly sold in Europe; some of it is used by the 'Bell' people of London; also by Messrs. Turner and Company, of Glasgow. About 1,000 tons are used annually in the United States; the larger portion being used in Germany.

The history of the Russian asbestos is not generally known. About 190 years ago—in 1720, asbestos was discovered in the Ural mountains, and 40 years later, under the reign of 'Peter the Great,' there was established, near the Neviansky works, a factory for the manufacture of asbestos articles; but the applications and uses for the mineral were very limited, hence the industry almost disappeared. It was not until twenty-five years, after the discoveries in Canada became known, that asbestos mining in the Urals was revived. The chief industry is now centred along the Sysert river, 30 versts from the Sysertsky works on the 'Asbestos mountain,' which is entirely composed of serpentine. The principal quarries are near the station of Baskenovo; the companies established at this centre comprise:—

(1) Poklevsky-Koziell Successors—producing 200,000 poods[1] per annum; (2) Baron Girardeau-de-Soukanton—150,000 poods per annum; (3) Korevo—130,000 poods per annum; (4) Kreutzer & Devallet—15,000 poods per annum; and (5) Baron Kusov—1,000 poods per annum.

According to Professor A. A. Inostrantxey[2]—a well known Russian geologist—the strip runs approximately 9 versts, and is about 600 sajens wide. There are others who affirm that the asbestos layers are 10 versts in length, and about 2 versts wide. Operations are everywhere on the surface, the width of layer not being precisely determined. The asbestos fibres are perpendicular to the surface of the vein, and are easily separated from the ore. The whole locality represents a sort of underground cobweb of asbestos, penetrating everywhere into the clefts and slits of the predominant serpentine.

About 20 poods of pure asbestos is obtained from a cubic sajen of ore, *i.e.*, approximately from 2 to 3 per cent. This asbestos is of excellent quality; it gives a thin, elastic, and strong fibre, from which a soft wadding is prepared. Pokleffsky's works are making thereof, different sorts of yarn. From a short-haired asbestos are prepared sheets for fireproof roofs, trimming walls, etc. The long-haired is worked separately from the short-haired. The long-haired is unwound on runners, and sifted on sieves with holes 2 square centimetres, on which the fibres remain; which are used for making an asbestos cartoon. The short-

[1] 1 pood = 36 pounds.
62 poods = 1 ton, of 2,240 pounds.
1 verst = 500 sajens, or 0·66 mile.
9 roubles 45 kopecks = £1.
1,000,000 roubles = £105,767.

[2] London Mining Journal, July 4, 1908, page 8.

haired asbestos is crumpled on light crushing mills; the fibres being precipitated in sloping recesses, and the turbid sediment sent to the precipitating reservoirs. The fibres of asbestos are worked like wool and cotton on combing machines, and jig-mills; and then a yarn is manufactured on spinning looms, which is afterwards worked into asbestos twist and rope.

The statistics show that the production of asbestos in the Ural mountains has been steadily increasing during the last fifteen years:—

—	Poods.		Poods.
1893	64,654	1900	234,756
1894	34,027	1901	268,537
1895	63,022	1902	275,183
1896	47,815	1906	489,680
1897	62,407	1907	571,194 = 9,356 gross tons
1898	101,633	1908	9,500 tons (estimated).
1899	164,430		

The exportation of Russian asbestos has not increased materially in the last three years. This seems to indicate, that the foreign manufacturers have not yet taken seriously to the employment of Russian asbestos in place of the Canadian product.

In the year 1907[1] the total Russian exports were 453,760 poods, valued at 1,070,122 roubles. The distribution was as follows:—

—	Poods.	Value.
		Roubles.
To Germany	140,471	440,725
To United Kingdom	93,273	281,121
To Austria	160,991	166,149
To Holland	27,951	84,762
To France	15,029	48,792

The exports from Russia for the last four years were as follows:—

—	1906.	1907.	1908.	1909. Up to end of Nov., only.
Poods	402,000	453,000	453,000	451,000
Value in roubles	840,000	1,070,000	1,131,000	1,129,000

[1] From Russian Official Export Returns.

The imports of asbestos: crude, fibre, and manufactured, for 1906, 1907, and 1908, were as follows:—

—	1906.	1907.	1908.
In lumps, poods	15,000	1,000	4,000
Value in roubles	48,000	less than 1,000	16,000
In powder or fibre, poods	6,000	5,000	7,000
Value in roubles	22,000	16,000	25,000
In form of pasteboard, poods	10,000	7,000	8,000
Value in roubles	74,000	43,000	57,000
In form of yarn or manufactures except pasteboard, poods	9,000	8,000	7,000
Value in roubles	86,000	75,000	70,000

The selling price of asbestos in the Ural depends on the quality of the fibres. Some time ago asbestos of the best quality was sold at 3·20 rbl. per pood; second quality 1·50 rbl.; and third quality from 1·20 rbl., to 1·50 rbl., per pood. Nowadays, the prices are much higher. But these figures refer only to small parcels, it being impossible to obtain large amounts; because all the above-mentioned large concerns have contracted ahead for the sale of their output.

Owing to the increase in prices, and the demand for asbestos, miners have begun to prospect other localities in the Ural. Thus in 1907, the Local Board of State Domains has issued to Mr. S. A. Podiakonov, Mining Engineer, nineteen permit certificates, to enable him to prospect for asbestos on the grounds of the Bashkirs, in the Province of Orenburg.

Considerable finds of asbestos of great body and fine quality have been made in the Orenburg (Russia) district, covering large areas. The discovery refers to two places, named Peyan-tchin and Ak-Zigit, respectively; the area of the latter asbestiferous ground being estimated at 48 square versts. The deposits are found in the form of large strata of serpentine, amongst siliceous schist and porphyry. The strata are intersected by many veins of serpentine, which contains the asbestos. These veins in many cases rise right to the surface; and where the ground is stony, and there is no soil on the top, they are quite visible. The veins extend to various lengths: varying from 350 to 1,400 feet, and even 2,100 feet; and it has been found that at that depth the mineral does not change in form, and that the quality even improves. The fibre taken singly seems to be quite white; but in bulk the colour is olive green. It is beautifully soft and woolly.

The average content in asbestos is 15 per cent; but at times, it reaches as high as 80 per cent. As regards quality, it resembles chrysotile. It is a striking fact, that at depth the quality of the fibre improves. The second deposit presents conditions and wealth of content similar to those of the first described, and to all appearance the volume of the reserves is equally large. It is added that two other areas are now being investigated, and that they show signs similar to those above enumerated.

The quarries are located in the Orsk district and are owned by the South Urals Asbestos Company, which Company has already built a factory and other

buildings on the ground. The properties are rented from the Bashkirs for a period of forty years. The rent of 10 kopecks per pood of asbestos is payable only on what the Company admits to be usable; but there is to be no payment for the first two years, except the over-all rent of 7 roubles 50 kopecks per verst.

Besides the above-mentioned concerns in the Ural, asbestos is mined by the joint stock company 'Isolator,' established in 1899. The asbestos mines of this Company are situated in the Miasski mining district in the south of the Ural; but the output in 1907 amounted to only 3,500 poods.

There are rumors that recently rich deposits of asbestos have been discovered in the Atlay Mining district, belonging to His Majesty's Cabinet. The concession for working these layers has been granted to Ymshenetzki Bros., Ural miners, who established a joint stock company 'Uralite'; but failed, and had to liquidate. The prospecting of these beds gave good results, and the firm are now looking for capital for the organization of their new enterprise.

Discoveries of asbestos were also made in the Yeniseisk province; but the results of the operations undertaken by some Paris capitalists are now known.

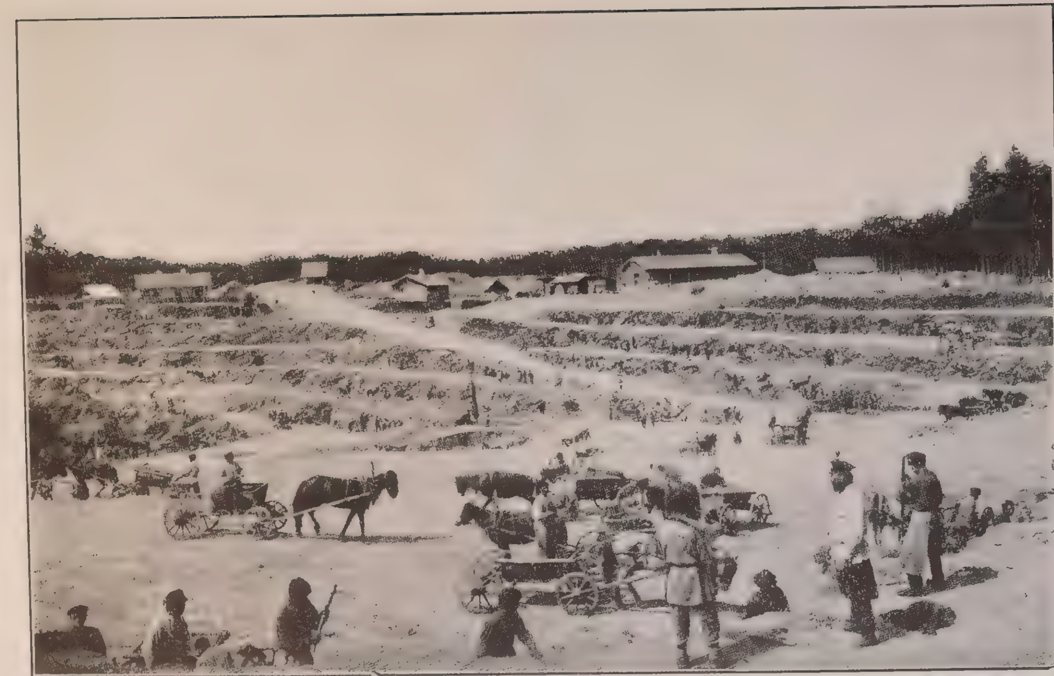
Recent reports are to the effect, that the principal asbestos deposits in the Urals have been sold to a German syndicate. The Korieff mine, the Poklieffsk mines, and the mines of Baron-de-Soukanton are said to have passed into German control. The Poklieffsk property includes the only mill operated in the whole region. The total annual output of the properties mentioned is about 470,000 poods, or 8,460 short tons; which is more than 80 per cent of the entire Russian yearly production.

The Ural deposits contain a large amount of white-yellowish, sometimes pale olive green, long fibre. Its quality, however, is not very high, and the mineral is used almost entirely in Europe to mix with Canadian chrysotile. For some purposes where an inferior grade can be utilized the Russian brand is used without any mixture; in the majority of asbestos goods manufactured, however, three-fourths Canadian asbestos is mixed with one-fourth Russian.

A report recently issued by Krijanousky on the 'Occurrence of Serpentine and Asbestos on the Beresovski, Kamenski, and Monoten Estates in the Ural Mountains,' translated by Mr. J. S. Diller, and published in the Mineral Resources Report of the United States, contains some interesting data regarding the deposits, and the asbestos industry generally. Extracts from this report are hereby presented:—

'The principal mines in Russia, as described by Krijanousky, are located about 57 miles north of Ekaterinburg, in the Ural mountains. According to Krijanousky's map, the mining district has a length of about 18 miles north and south and a width of from 2 to 3 miles. The mines are limited to a mass of serpentine, which is bounded by schist or slate on the west and by granite on the east. In the northern and southern parts of this mining region the mines are not as productive as those in the middle portion of the field, where the mines of Baron Girard and Korff are situated.

'The gneiss of the serpentine is suggested by the associated diallage. The serpentine is cut by dikes of diabase as well as porphyry, and by a few veins of quartz. The asbestos is not found everywhere in the serpentine, but is confined to ellipsoidal portions which invariably have their longer axis north and south, these portions sometimes attaining a length of 3,500 feet



From Becker and Haag, Berlin. Transport of asbestos rock from quarry to mill in Russian asbestos quarry.

and a width of 1,000 feet. Generally within each ellipsoid the eastern and western borders are less rich than the central portion running north and south. The veins of cross-fibre asbestos run generally north and south with vertical dips, although some of the veins are nearly horizontal. Masses of slip fibre are present, but not abundant. The richest ellipsoidal masses bearing asbestos occur in the middle part of the field. Where richest, the yield is from 42 to 55 pounds of asbestos per cubic yard; while in the other mines to the north and south the yield is from 28 to 33 pounds per cubic yard.

'Krijanousky describes in detail the Russian method of milling asbestos and grading it in preparation for the market. The fibre is separated into five grades, according to length, ranging from 4 centimetres down to about one-half centimetre. His paper is the most important the writer has found regarding Russian asbestos.

'The actively producing mines of the Ural, as already stated, are north of Ekaterinburg. Although actively mined for only about 20 miles, asbestos has been reported at many localities to the south for a distance of 200 miles from Ekaterinburg to Orenburg, where active prospecting is now going on.

'In Siberia, although an output is reported from only one mining region—that of the Minusinsk, on the Yenisei river—asbestos is reported from many localities in the Altai Mountain region and to the southward, but of the real value of these deposits little knowledge is yet available.

'Of late years Russia has become an important producer of asbestos. The mines are as yet of only local development, but the abundance of the asbestos, its relations to market, and the cheapness of labour indicate that Russia will appear in the not distant future a much larger producer than to-day.

'In general, it should be said, however, of the Russian asbestos that it is much harsher to the touch than that of Canada and less suitable for spinning. This may be due, at least in part, to the fact that the mines are in shallow, open-cuts and the rocks decidedly affected by weathering. The region is flat and not well drained, so that the open, shallow mining pits encounter an abundance of water, which is greatly to their disadvantage. Furthermore, much of the region is covered with glacial drift and forest and the working season is short and interrupted. The working season lasts from May to October, but as most of the workmen are farmers, who must attend to their farms in July and August, the mine work is interrupted for two months. The mines are said to employ 15,000 men, chiefly peasants.

'According to Consul-General Hunter Sharp's report from Moscow, February 12, 1909, there was in 1905 a total output of 7,894 tons of asbestos from the Russian mines, which varied in price f.o.b. at the mines from $25 to $117 per ton. The greater part, 6,495 tons, came from the Perm district of the Urals; the remainder, 1,490 tons, came from the Minusinsk mining district on Yenisei river, not far from the Trans-Siberian railway.

'Asbestos was discovered in the Ural mountains nearly two hundred years ago, but it was not until about 1885, when Baron Girard took hold of the matter, that systematic development began. The methods employed at first were primitive, but they have steadily advanced until at the present time some of the mines have modern equipment with electric power.

'The mines are broad, shallow, open-cuts, and the serpentine is generally so soft as to be easily mined with a pick. In the deepest workings, 70 feet, the rocks are becoming more solid, and explosives have to be used.

'The growth of the Russian asbestos mines is indicated by comparing the total output of 1,167 tons in 1893 with 10,308[1] tons, the output in 1907, a relative advance which approaches that of Canada for the same period.'

Fresh discoveries have recently been made in the Province of Yeniseisk, Siberia; and the following is an abstract of a report by a German engineer on these occurrences:—

These deposits are located in the district of Askisk, on the right bank of the River Kamyschto, a branch of the river Yenisei, Province of Yeniseisk. Their distance in a straight line from the river Yenisei is fifty-two miles, and about 105 miles from the Chinese boundary.

The asbestos containing formation takes in the foothills of the Ssajansk mountains in the vicinity of the Kamyschto river. Exploration work consisting of prospecting trenches, canals, and drifts, shows the existence of asbestos in many places: partly outcropping, and partly covered by alluvial overburden. The mineral is found in both the serpentine form *in situ,* as well as in fine fluffy fibre; the latter the result of an atmospheric disintegration. The most explored territory is sixteen miles square; while on another sixteen miles square asbestos has also been located; but very little work has been done. The containing rock is serpentine, accompanied by crystalline limestone. The asbestos veins have a thickness up to 2″, and are arranged in the serpentine in parallel layers. This asbestos has a silky appearance, with a yellowish colour; and when fiberized between ones fingers, produces white, finely divided threads.

These deposits are located in a very hilly country, divided by deep intervening valleys. The summits of the hills are devoid of any covering, and clearly expose the asbestos bearing formation for a considerable distance. The relief of the country offers cheap mining in quarries and in tunnels along the serpentine asbestos gangues; and on account of the solid character of the rock, not much timbering is required in the workings. Wood for supports in the underground works can be procured in sufficient quantities, in close proximity.

Workmen can be obtained from the local population, or from the gold mines, which are being operated now, at a distance of about three miles. At the start it would, perhaps, be better to import miners from the Urals; but later the local miners may be added to supplement the working force.

Fuel for power purposes can be obtained from coal mines located at a distance of twenty-eight miles from the locality.

Transportation of asbestos may be effected for five months during the open weather, on a wagon road to the banks of the Yenisei river; and then by boat to the railway station Krasnoyarsk. The total cost of the transport is 20 kopecks per pood, or about $6 per ton. It is estimated that the freight charges from Krasnoyarsk to London will be in the neighbourhood of $25 per ton; hence the total cost of transport per gross ton from the mines to London will be about $31.

In his résumé, the author of this report says there is an excellent chance for the establishment of a profitable industry. He dwells at length upon the underground methods of mining these serpentine asbestos gangues, through tun-

[1] From other sources it appears that only 9,356 gross tons were raised.

From Becker and Haag, Berlin. Step-like exploitation of Russian asbestos quarries.

nels, galleries, etc.; and winds up by saying that, through this manner of winning the mineral, the cost of production can be considerably reduced.

The *Krasnoyaretz* says, that in Krasnoyarsk, a joint stock company has been formed amongst the local mining firms and some French contractors for the purpose of working the asbestos deposits in the Minusinsk district, near the village of Batterei. The deposit, says 'The Journal,' is a 'very' rich one, and all the local circumstances favour its development, particularly as it lies in a very populous district, about 10 or 12 versts from the Yenisei river.

It was also reported in 1907 that an asbestos discovery had been made near the Aliberovsk graphite mine in the Tunkinsk district.

SIBERIA.

It was reported in the middle of 1903, that discoveries of asbestos deposits had been made in different parts of Siberia; the principal one being situated in the Irkutsk district, 1½ miles from the Kitoi river: and a company has been organized to develop them. Preliminary tests are said to show that at a depth of one foot, the asbestos is equal in quality to the Canadian, and superior to the Italian product. The Kitoi river affords ample water power and cheap transportation to the railway.

Mongolia.

According to Mr. Riehle—Manager of the Frontenac Asbestos Company, East Broughton, Que.—who made a trip to the Ural mountains and Mongolia on behalf of the 'Asbest and Gummiwerke,' Alfred Calmon of Hamburg—asbestos occurs in Mongolia in a country located at a distance covered by a 25 days overland journey south of Lake Baikal. The whole region is very hilly, and some parts are even mountainous. It is very inhospitable, and is heavily covered with forests, and the valleys are all swamps, through which travelling is exceedingly difficult. Some of the mountains attain a height of 2,000 to 3,000 feet. A nomadic tribe of Mongolians—the Buriats, not industrious, and not very intelligent, roam through the country, herding cattle for a living.

Asbestos occurs in the Boo-koo-sun mountains and in the El-cheer and the Otkinsky Karoo ranges. The most important occurrence lies in the El-cheer range. Here the serpentine is, as a rule, massive, but very much decomposed. Freshly broken, it is a semi-opaque rock of a greenish tint; but when exposed to the air, loses its colour; changing to grey. The asbestos is of a brownish tint, and of excellent quality: the fibre being from ¼″ to 1½″ long. No mining has been attempted in these inhospitable regions; and on account of their remoteness it is not very likely to be undertaken in the near future. About three day's journey due south from the Mongolian frontier in Krasnoyarsk, some brownish-yellow asbestos has been found in concretionary masses, of a similar character to those in Templeton. The veins, however, cannot be distinguished well in the rock, owing to the similarity of colour; only when the asbestos is fiberized by hand is the true composition of the rock revealed. No mining is carried on in this country, owing to its inaccessibility.

Finland.

In the beginning of 1904, a communication was received calling attention to the occurrence of asbestos of commercial quality in central Finland. A company was organized to explore these deposits, and operations were subsequently carried on for some time. In colour the asbestos is pure white, and by its soft fibrous nature is suited for spinning, and for the manufacture into board, and insulating materials. The property is situated about half way between Kuopio and Toensu: near the railway connecting these towns. No reports regarding this undertaking have been received lately.

Italy.

There is very little asbestos being mined in Italy: in fact the Italian manufacturers of asbestos import Canadian fibre. The native asbestos belongs to the hornblende variety, which occupies pockets and chutes in serpentine. It is, to some extent, brittle, and only a small percentage of it can be applied to spinning. The United Asbestos Company, of London, England, is about the only Company that uses it to any extent. There is none sold in the United States at the present time. A few carloads only, are now annually used by manufacturers in Germany.

The Italian fibre is mostly applied in the manufacture of mill-board; it is also utilized in spinning, but is chiefly mixed with cotton, or fine copper wire. In ancient times it was used for making grave-clothes, and the Museum at Naples contains several of the shrouds for wrapping corpses. All these garments contain cotton in a more less degree.

Prior to 1880, asbestos was only mined in Italy; but the uses being very limited, on account of the exorbitant prices asked for good fibre, the production, with very few variations, remained the same; but when Canada—with its vast resources of asbestos, entered the market, the whole industry assumed a different aspect. Italian producers soon found that they could not compete with the Canadian mineral for the following reasons: (1) mining is very difficult on account of hand labour: which is compulsory owing to the character of the ground; (2) supply is very uncertain; and (3) the fibre is much more difficult to deal with than the Canadian asbestos, requiring different and more complicated machinery.

Further, it is also reported that the quantity of the better class of fibre is limited.

Although the two species of asbestos—the Canadian and Italian—are so entirely different in their physical characteristics, chemically speaking they are very similar, and for certain applications may replace each other.

Italian asbestos is a fibrous form of hornblende, and is different both in form and appearance from the Canadian species, which is generally termed chrysotile. Both the Canadian and Italian varieties possess some fine qualities and characteristics, and each finds its special application. Manufacturers even say that, in some cases, a mixture of both gives better results; and is superior to the best quality of either of them used separately.

Specimen of asbestos from the Uralit mines, near Bajenowa station, Asiatic Russia. The specimen is a conglomerate of asbestos. decomposed serpentine, roots, and fibre from the surface vegetation. This class of material is found in considerable quantity, and mnst be treated by wet process to prepare it for the market.

The chemical composition of Italian asbestos is very nearly the same as that of the Canadian mineral, as may be seen from the comparative analysis made by Professor J. T. Donald, of Montreal, page 80.

According to Mr. Alfred Fisher[1]—the General Manager of the oldest asbestos company in existence, namely, the United Asbestos Company of London, England—Italian asbestos mining may be considered to have commenced with the nineteenth century.

We find that about one hundred years ago, two enterprising citizens of north Italy conceived the idea that what had been done in ancient times might be undertaken for modern requirements; and that a cloth made of this material would answer well for various purposes. They carried out some experiments in Lombardy, which, to a certain extent, were considered satisfactory, and which earned for them some honorary distinctions from Napoleon I; who was always ready to encourage science, art, and industry. The numerous dynastic crises, however, which kept this part of Europe in a perpetual state of disquietude, prevented the development of the trials, and for a further space of years asbestos seems to have been looked upon as a material of some interest to the curious, and to the mineralogist and geologist, but of little or no practical, commercial, value.

It was not until the year 1866, that Signor Albonico, having given some attention to this product of the mountains of his native Province, put himself into communication with a highly cultured and intelligent Florentine cleric, Canon del Corona, with a view to obtaining his assistance in developing the economic uses of asbestos. They were subsequently joined by a distinguished Roman nobleman, the Marquis di Baviera.

The result of their researches and experiments was, that they produced some asbestos cloth and paper, and were in hopes of obtaining a contract from the Italian Government for the supply of the latter for bank notes and other securities. In this enterprise they failed; and whatever prospects they may have had of better success in other directions, these prospects were frustrated by the outbreak of the Franco-German war of 1870-71.

Signor Albonico had, however, obtained concessions from several communes giving the right to work deposits of this material on their respective properties; and having transferred his rights to the Canon del Corona and the Marquis di Baviera, he thenceforward acted as their agent until the mines and mining rights were transferred to other parties.

The first district in which asbestos of commercial value was obtained, was the Susa valley, which is approached from France through the famous Mont Cenis tunnel. On emerging from the tunnel on the Italian side, the line follows the southern mountain slope with a gradual descent, overlooking the town of Susa, which gives its name to the valley. At a point in the centre of the valley, and on the northern mountain slope, are the places from which the floss asbestos fibre—the appearance of which in gas stoves is familiar to us—is obtained. In the same locality is also found a fine, white powder of asbestos, used for paint

[1] Paper read at a meeting of the Institute of Marine Engineers, Stratford, Eng., April 12, 1892.

and other purposes. The ground from which these materials are obtained is about ten miles square in extent, and the works are carried on at a height of from 6,000 to 10,000 feet above sea-level. The temperature is, of course, low at such an elevation; but the inhabitants are hardy, robust, and industrious. The works are reached by mule-paths for some distance; but the remainder of the way has to be travelled on foot, and from four to five hours are required for the journey from the plain on which the railway and high road are situated. The first work done here in recent times dates from 1876. The method by which the material is brought down the mountain side is, by loading it on a kind of toboggan or sledge, which slides as easily over the rocks as over snow; and so expert are the inhabitants at this work, that two men can bring down 8 hundredweight of asbestos in three hours.

The second district—in the Aosta valley, commences at Ivrea, a town of some importance, about forty miles in a nearly northern direction from Turin. From Ivrea to Châtillon—a distance of a little under thirty miles—the railway passes through the heart of the asbestos properties, which flank it on either side, the direction being northwesterly; and at the latter town (Châtillon) the valley trends sharply to the west until the city of Aosta, the ancient Augusta, is reached.

The history of the asbestos mining industry in this Province is as follows:—

In the year 1849, Signor Antonio Re, of Rome, finding himself implicated in certain political troubles, took refuge in this valley, where he lived for many years. In 1873, he became aware of the proceedings of the Marquis di Baviera and the Canon del Corona, and set to work to investigate the question of asbestos in the Aosta valley. He, like others, was aware of its existence; but until then the mineral found in this district had been considered of inferior quality, and not serviceable for industrial purposes; hence no trouble was taken with it. In the year named, however, Signor Re undertook a search for some better qualities; and having assured himself that such could be found in abundance he opened communication with the London parties, and they, being satisfied with the material, started working on a large scale.

It is impossible to give, with any degree of exactitude, the extent of the asbestos bearing ground in the Aosta valley; but as the valley is some seventy-five miles in length, and varies in width from five to forty miles, some idea may be formed of it. Notwithstanding the large quantity of asbestos that has been already obtained, enormous deposits remain untouched, and the yield may almost be considered inexhaustible.

The quality of asbestos in the Aosta valley is not, however, similar to that in the Susa valley; but it is of the kind known as 'grey fibre.' It is long, strong, and soapy to the touch, and is similar to that obtained in the third, and perhaps most important of the vast asbestos areas.

The third district is situated in that portion of Lombardy known as the Valtellina. To reach it from the valley last described (Aosta), it is necessary to return to Turin. From thence a railway journey of about three hours and a half brings one to Milan. A further journey by rail of about two hours, brings one to Como, at the foot of the lake of that name. The route is then by steamer to Colico, situated at nearly the northern extremity of the lake; or by a new line

direct from Como to Sondrio—the chief town of the district. The line is now open. The railway follows the course of the river Adda. An affluent of the Adda—the Mallero—flows through the valley of Val Malenco. In this valley and in others branching out from it to the east, are the asbestos mines. It was in this region that Signor Albonico commenced his researches.

The district is divided into five Communes, and the asbestos properties have an area of about 25,000 acres, or nearly forty square miles. The population numbers about 7,000, of whom a large proportion is engaged in asbestos mining. Throughout the whole of this extensive area the mineral is found in abundance, and of the finest quality. There is in the United Asbestos Company's exhibit at the Crystal Palace a specimen of the crude mineral in one piece, which, for quality, was considered to be the finest in the world and which weighed forty-five pounds; but even this is far surpassed by a block from the same Company's mines, weighing nearly 3½ hundredweights.

For a distance of eleven miles of the twenty which form the length of the Val Malenco, there is a good carriage road; but beyond that the ascent to the mines is by following mere goat-paths; and as the slope of the mountains is steep, the labour of bringing the mineral to the road at the bottom of the valley is very great.

The surface of the ground is, for about one-third of its extent, pasture and woodland; the remainder being bare rock, which admits of easy examination and trial. The greater part of these mountains is as yet unexplored; but indications have been observed which lead to the conclusion that the supply of asbestos is practically inexhaustible.

The height above sea-level of this mine, so far opened out, varies from 3,600 feet to 7,200 feet. The climate is, for such an elevation, comparatively mild; there being some places at a height of 6,000 feet where work can be carried on during the whole year.

The inhabitants work willingly at the asbestos mines, in spite of possible danger from landslides and avalanches, which, however, are now almost unknown.

For a long time the opinion was held that at a certain depth, greater or less according to circumstances, the veins of asbestos would terminate in the serpentine rock; but recent experience has proved, that by following the direction of the vein, it is recovered. The fibre at the greater depths is of better quality, and less indurated than that near the surface. The work is carried on by means of shafts and galleries; dynamite being used for blasting purposes.

The Italian ore is taken out in lumps, forming hard, closely compacted bundles of fibres, varying from light grey to brown. Sometimes threads of many feet may be drawn from such bundles, and the fibre then has the appearance of flax.

All asbestos mined during the day is dried, bagged up, and transported to the factories without any further preparation. The crude asbestos is separated into three grades: (1) the long fibre for spinning and weaving; (2) the short fibred material for the manufacture of mill-board and paper; and (3) the shortest kinds, being reserved for other purposes.

Recently, a discovery of asbestos was reported at Mount San Victoreo, near Lanzo, Torino, and the quality is said to be fairly good.[1]

France.[2]

Small deposits of asbestos are worked in the Pyrenees, in Dauphiné and in the island of Corsica. The production last year is not reported.

Cyprus (In the Mediterranean).[3]

The Cyprian Mining Company—an Austrian corporation with a capital of about 400,000 crowns (about £16,700), has been formed to exploit the asbestos deposits at Trodos, Cyprus, which are stated to be very extensive. The Company have secured important concessions and mining rights from the Cyprian government, and have already begun work on a limited scale. A first consignment of about 30 tons found a ready sale at good prices, the asbestos being of good quality, and this will improve as the mine is opened up.

Under the terms of their license from the Government, the Company were bound to export within the first year of their operations, a minimum of 75 tons of asbestos. Up to March 1, 1909, they had exported 457 tons, on which a royalty of 10 per cent was paid to the Government.

The Company have expressed themselves as well satisfied with the result of their prospecting and preliminary operations; further importations of machinery are being made, and there is every prospect of a very extensive business being carried on. Their success has given a great impetus to the prospecting for minerals, and 57 prospecting licenses were issued during the year to persons in search of copper, asbestos, magnesite, coal, and similar deposits.

Queensland.

For many years asbestos has been known to occur in the serpentine belt which extends in a northwesterly direction from Balnagowan, near Keppel bay, to Yamba, Princhester, and Marlborough, in the Rockhampton district.

Near Princhester there are some old workings which were opened many years ago to determine the character of the asbestos deposits there.

The country rock is serpentine, and the veins of asbestos occur in all sizes up to 12″ or more in thickness. The asbestos in the larger veins is coarse in texture; but one sample from a seam about 2″ thick, showed asbestos of much finer quality. All the samples were much iron-stained, and partly decomposed by the action of surface water, the workings not being deep enough to obtain the asbestos unaltered.

Messrs. Hall and Stokes, in a paper read before the Royal Society of Queensland,[4] described the asbestos deposits occurring near the junction of Tilpal, Princhester, and Glen Prairie; and in their summary regarding the occurrence

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[1] Mineral Industry, 1906, page 56.
[2] Engineering and Mining Journal, June 20, 1908, page 1,250.
[3] Report of the High Commissioner for Cyprus for 1908-9.
[4] Proceedings of the Royal Society of Queensland, 1890 to 1893, Vols. VII, VIII, and IX, page 120.

of asbestos and the prospects of establishing an asbestos industry, state their belief 'that, on proper search being made, veins of asbestos of good quality and payable size will be discovered and that a permanent industry will be the result.' They also think that 'a wide knowledge of the modes of occurrence and methods of working may lead to search being made in other serpentine areas.'

The material obtained recently, when microscopically examined, showed the fibres to be finer than the best quality of Italian asbestos; but no further comparison could be made, as the sample was too much decomposed; neither, for the same reason, could the structure of the individual fibres be examined to determine their fitness for weaving purposes.

South Australia.[1]

Asbestos has been mined in this country at Red hill, about nine miles easterly from Broken hill, in the Rockwell paddock, where for a long time prospecting had been going on on the side of the hill, in which asbestiform rock was known to exist. Several veins of true asbestos similar to the Italian variety have been discovered, and mining has been carried on for some time by the Australian Asbestos Manufacturing Company. It is reported that specimens 28″ in length have been found. The staple article ranges from a striated salmon tinted variety—known as picrolite—from near the surface; to a beautifully white, flossy fibre of considerable length and good tensile strength, taken from the shallow depth of 20 feet.

On the top of the hill, veins of coarse chrysotile—the Canadian variety—are found in a ferruginous gangue of what appears to be chrome iron ore. Lower down, a promising vein has been opened; while to the eastward is a deposit of amianthus which seems to be of considerable extent.

A discovery of asbestos has been made on government lands ten miles from Hawker, on the old Arkoba station, South Australia, and several tons of substance have been mined. The asbestos seems to be a 'crocidolite' or 'blue asbestos,' as found in Griqualand, South Africa. Mr. W. S. Chapman, Manager of the Adelaide School of Mines and Industries, has given the following assay:—

Water	3·71
Silica	51·33
Alumina	3·93
Ferric oxide	17·66
Ferrous oxide	4·10
Lime	1·32
Magnesia	12·18
Soda	5·91
Potash	0·13
	100·27

New South Wales.[2]

Liversedge reports a dark green coloured asbestiform mineral; but no mining has been attempted. As a rule, asbestos in this country is closely associated

[1] Canadian Mining Review, 1891, page 200.
[2] "Asbestos," by Jones, 1897, page 73.

with chrome iron ore deposits and other minerals. The colour of the asbestos is generally white, or of a light greenish blue, densely compacted; but easily separated into fibres. The Native Asbestos Company, established for working up the Australian ores, is located at Melbourne, Victoria.

Western Australia.

Much interest is now centred in the new discoveries made in the Pilbarra district. The Pilbarra Asbestos Company of London, England, have selected leases amounting to a total acreage of 316 acres, and the latest reports show that they have sunk shafts to a depth of 140 feet, have proved the continuance of the ore lode towards depth, and the existence of large quantities of *lode* matter in various degrees of richness in both of the Company's lodes that are traceable on the leased territory. It appears that for the extraction of 'crude,' a considerable quantity of lode matter has to be raised, which at the present time, as no milling plant is on the premises, has to be stored away. A large sample sent to the office of the writer, for examination, indicates that, although much of the fibre does not possess the high degree of tensile strength found in Canadian asbestos, yet some good crude may be secured. The samples examined, showed a highly brilliant, wavy lustre, rarely found in the Canadian, except in the Laurentian or Templeton asbestos; while the length of the fibre ranged from a fraction of an inch to 5″. The fibre is a chrysotile-asbestos; the crystallization in all the samples examined having taken place vertical to the walls. A ribbon-like structure, similar to the Canadian Laurentian asbestos, seems to be the predominant feature of the occurrence; the smaller fibre evidently furnishing an excellent material for milling.

Mr. Herbert Soanes, Asbestos Specialist, of Perth, Western Australia, has made quite an extensive study of the 'Pilbarra' deposits, and has placed considerable data at the disposal of the writer. An abstract of his private report is hereby presented:—

> 'The geological belts, of which there are several, in one of which the "Great Golden Mile Gold-Mines" occur, are found to run in a northerly and southerly direction, for a distance of from twelve to fifteen hundred miles, and each with a breadth of from twenty miles upwards. The geological age attributed to the latter and a parallel belt is 'Archæan,' and this series is considered to be more largely developed here than in any other portion of the world.
>
> 'In the immediate vicinity of the discovery the serpentines are largely developed, occurring in large parallel dikes of from a few to eighty chains in width, with dikes of diorite, and numerous razorbacks of laminated chert, as roughly shown upon plan attached hereto.
>
> 'The various formations as described—with perhaps the serpentine predominating—trend in a northeast by southwest direction, and have a lateral measurement of several miles, whilst their linear extension is considerably more, but owing to the limited nature of the departmental field work accomplished, it is quite impossible to supply anything more than a very approximate indication of its extent.
>
> 'Again, referring to the rough sketch plan, it would certainly appear that the two lodes No. 1 and No. 2, as indicated thereon, are contact lodes,

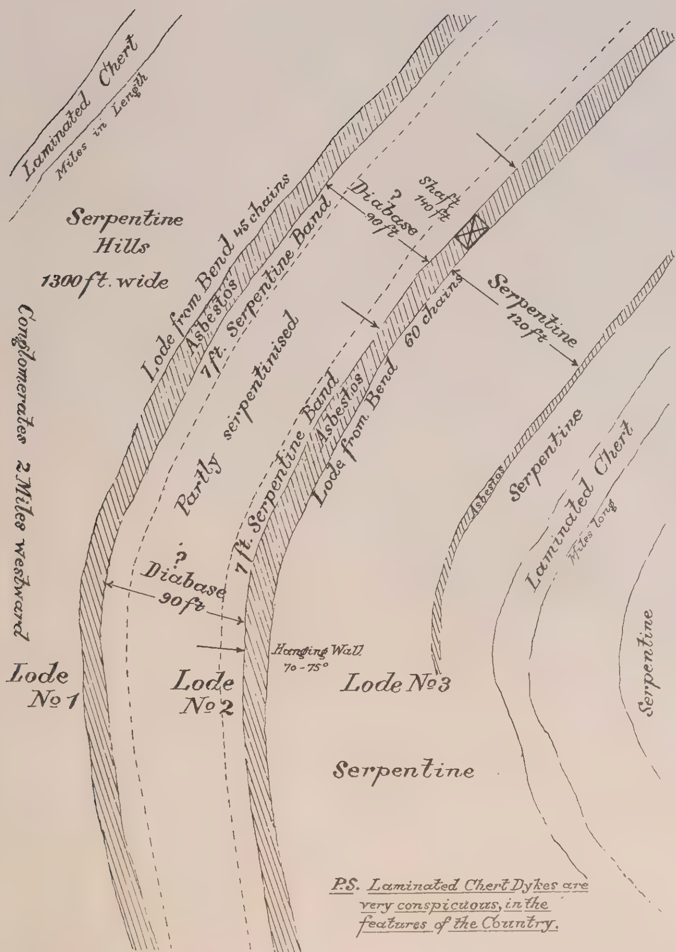

FIG. 51.—Occurrence of asbestos in Pilbarra district, Western Australia. (By Herbert Soanes, Perth, W.A.)

which from development work carried out to a depth of 80 feet in the case of the former and 140 in the latter, and from the exposing of good clean walls in each case, would appear to substantiate.

'The surface of these lodes, No. 1 and No. 2, are about upon a level, whilst that of No. 3 is elevated quite 100 feet above the former, and which occurs within a few feet of the contact of the serpentine with the laminated chert dike, about 100 feet in width, and although this latter lode is not too clearly defined, it would appear to vary from 1 to 4 feet in width and to have a linear extension of approximately 400 feet.

'The serpentine formation lying between No. 3 and No. 2 lodes has a varying width of from 120 feet to 180 feet, and the colour is also found to vary from an olive green to a purplish hue; the latter variety under the microscope is seen to be a massive structureless serpentine with numerous inclusions of black and brown iron ore. The sample examined was taken from near the surface and may have been found to have altered considerably at depth.

'The No. 2 lode, upon which the most of the work has been expended, has a width of from 2 to 6 feet, or an average in the vicinity of 4 feet, and is found to be of a lenticular nature. It can be traced along its outcrop for a distance of at least 50 chains (3,300 feet), and although the fibre in the outcrop cannot be said to be continuous, it is significant to note that, at the 140 ft. level, where some 250 feet of driving has been accomplished, the fibrous veins have not only been found to have improved in quality beyond expectation, but the quantity has improved also, and the fibrous matter has become continuous.

'In the writer's opinion, there can be little doubt that the great majority of the hand cobbing ore will be found to occur in the lens form, the length of which to estimate would at the moment be mere conjecture. However, one of these lenses, which was worked near the surface, was said to have had a length of about 25 feet, whilst at the 140 ft. level, the identical lens had been proved some 20 feet, and was still in the face when operations were suspended for the time being, which under the circumstances was very unfortunate, seeing that this work must prove a most important development, proving as it would whether the lens which is said to be dipping away to the northeast at an angle of about 45 degrees, is lengthening or shortening at that depth, and although this is the only high-grade lens exposed so far, there can scarcely be a shadow of doubt that this characteristic will be found upon development to be repeated at intervals along the lodes.

'It is estimated that the high-grade lens referred to above will produce 50 per cent of fibre of all grades, including a high return of No. 1 and No. 2 grades, whilst the remainder of the lode opened up will return quite 30 per cent of all grades, although owing to the lack of a treatment plant, these estimates must be taken as approximate. However, I am of the opinion that the lower grade matter will not produce in proportion the same amount of the higher grades of fibre.

'The formation found between No. 2 and No. 1 lodes varies in width between 60 feet and 90 feet, and with the exception of a few feet upon either of the contact sides of each lode it is not completely serpentinized, as demonstrated by a sample taken from a depth of 20 feet, which still preserves some of the structure of the original rock in the shape of partly altered olivine crystals, and grains of ilmenite with leucoxene. Another sample taken from near the surface and the lode, upon examination was found to consist largely of serpentine, and appeared to approach in character the serpentinized augite picrites of some parts of Cornwall.

'No. 1 lode is very similar in character to No. 2, and outcrops for a considerable distance, being very little short of the No. 2 lode; but owing to the limited amount of work done upon this lode, very little data are available. It has, however, been sunk upon to a depth of about 80 feet, and its dip ascertained to coincide with that of the No. 2 lode, which is about 75 degrees to the southeast, and its walls to be quite smooth. The fibre content is estimated at about 30 per cent, and together with the whole of the lode matter will probably find its way to the mill.

'In summing up the possibilities of these two lodes, I venture to state that upon development, I would not be surprised to find their linear extension from 100 chains or more, and development work should be pushed on to a few feet below water level—which has so far not been attained—and the subsequent cross-cutting from the No. 1 to the No. 2 and No. 3 lodes."

The production of asbestos in the 'Pilbarra' district, in 1908, amounted to 40 tons, valued at £1,000.

The *Standard of Empire,* London, published an announcement that asbestos had been discovered in Gundagai. Upon the recommendation of a European expert, 40 tons of asbestos were sent to Germany to test its commercial qualities and value. The prices are said to be parallel with those for the Canadian product. It is claimed that the quality is superior to the Russian and Italian. Machinery is said to have been ordered for the treatment of the lower grade material.

New Zealand.[1]

Some time ago, an Auckland syndicate acquired an asbestos area in the Takaka district, near Motueka: from which they took out 3 tons, and consigned the same to customers in England, and are reported to have received a return of £20 per ton, with the advice that if the ore had been more carefully prepared it would have realized considerably more. In the opinion of the highest recognized authority in Canada—who has examined the deposit—the quality of the asbestos is first-class. The syndicate will now deal with the question of development.

West Griqualand—Africa.

Asbestos has long been known to occur in West Griqualand; and at one time mining was carried on over an area of 30,000 acres. The asbestos, according to Mr. H. T. Odds, has a peculiar lavender blue colour; caused by the large proportion of iron protoxide it contains. It differs from the other varieties of asbestos, such as the Italian, Canadian, and Russian, not only on account of its blue colour, but in being of lower specific gravity. It is generally found in veins, seldom less than 2″, and more often 4″ and 5″ wide, formed of closely compacted parallel fibres which run from wall to wall of the vein, without break or fault. The grain is very fine, and even in the rough state the fibres are singularly distinct. The fibres are somewhat elastic, and easily separable by the fingers. Several veins have been found, regular in extent, and the fibre always lies at right angles to the sides of the deposit. The enclosing rock is a dark brown shale. The character of the rock varies considerably: in some places it is

[1] 'The Standard' London, February 4, 1909.

soft, in others hard. The better quality of asbestos occurs in the hard rock. The composition of the asbestos is given as:—

Silica	51·1
Protoxide of iron	35·8
Silica	51·1
Magnesia	2·3
Water	3·9

The output during the year 1898 was on an average about 100 tons a month, and the prospects for an increase seemed very bright. Native labour was employed under European supervision. Very little skilled labour was required; the mining being mostly surface work, or by shallow adits run in the sides of the hills. The cost of extraction of one ton of asbestos, even with the primitive mining methods, was on an average only $24.

It has most of the striking qualities of white asbestos: is uninflammable, heat proof, and unaffected by atmospheric influences, and is a non-conducting material. It is stronger than the ordinary asbestos. In cobbing it breaks away from the matrix with a clean fracture and without any fragments of the latter adhering. It is a most efficient covering for preventing loss of heat and condensation, and consequently, in the economizing of fuel. The following gives the average results of two sets of experiments made in 1896. Column No. I shows results with bare pipes; No. 2, with pipe covered with blue asbestos mattress, having 1″ asbestos cord over it; No. 3, pipe covered with 1½″ blue asbestos cord, having small asbestos string between:—

Description.	No. 1.	No. 2.	No. 3.
Pounds water condensed per hour	12,225	3,152	3,484
Pounds water condensed per sq. ft. per hour	1,698	0,437	0,484

In the above experiments the average steam pressure was 95 pounds; the average engine room temperature 57°; and the surface of each pipe 7·2 square feet. The asbestos can also be used for packings and joint materials. The wool is capable of being spun into very fine yarn of great tensile strength: which can be woven into netting twine, ropes, and cordage of all kinds. A composition is also made from the blue asbestos for rendering cement and other materials unattackable by acid liquors or vapours.

Notwithstanding all these merits, the business connected with the exploitation of these deposits has not been prosperous. At the annual meeting of the Cape Asbestos Company on October 11, 1898, it was stated that the operations of the previous year showed a loss of £3,808. Although the blue Cape asbestos was claimed to be as good as, or superior to, the white or Canadian asbestos for many special purposes, it was nevertheless admitted that the introduction of this mineral into the trade was not making the rapid progress that was looked for. In 1908 the sales amounted to £9,000; in 1899, to £15,000; in 1900 to £15,550, while the first six months of 1901 indicated a business of £9,000. To cover, however, all the expenses, sales of at least £25,000 would be required.

In 1902, according to official reports, the production sank to £1,600, and in 1903 nothing was stated in the reports.

Recent advices from Griqualand seem to indicate that asbestos mining has been revived in 1907 and 1908: and the following extract from a report published in the '*Money Market Review*,' London, June 26, 1909, will be found interesting:—

> 'Satisfactory progress was made by the "Cape Asbestos Company" in 1908, notwithstanding the general trade depression. The year's operations yielded a net profit of £6,900, after deducting the sum of £3,800 for depreciation, so that the directors are able to wipe off the debit balance remaining a year ago as well as the remainder of the goodwill of the Company's 'Turin' business. A credit balance of £2,100 is then shown, and the directors propose to carry it forward. The company, though established in 1893, has never yet been able to pay a dividend, but if recent progress is maintained, the payment of a maiden distribution should soon be possible.'

Apart from the 'Cape Asbestos Company' another syndicate has taken up asbestos mining and it is reported that the production which in 1908 was 300 tons will be considerably increased during 1909.

The prices for 'Cape' asbestos range from 600 to 1,300 marks ($140 to $310) per ton. The 'Blue Cape' asbestos, is used principally for insulating purposes, in the manufacture of mattresses and boiler coverings.

Transvaal (District of Carolina).

The discovery of asbestos in this district, in 1906, has attracted some attention, and quite a number of properties have been taken up. They are located about twenty miles from Carolina, in the low veldt; the first discovery having been made at Diepgezet, and Silver Kop. It is further asserted that the asbestos is of excellent quality, and can—according to the report—be separated and cleaned without the aid of machinery.

The asbestos occurs in serpentine, cutting a cherty formation with bands of manganiferous earth. The latter, on account of its loose condition, is likely to give considerable trouble in mining. The mode of working the asbestos on a large scale has not been decided upon. Mining and shipping, it is said, may cost as much £20 per ton, and a profit of from £15 to £20 is anticipated in view of the excellent market conditions. According to the statement of the miners, the only treatment necessary is 'cobbing.' This it is believed will not cost more than 10s. per ton. No expensive machinery is required. The nearest railway station is Wonderfontein, about fifty miles distant; but the new Springs Eastward line will bring the property within half that distance. Native labour is at present scarce. The Carolina asbestos is of abnormal width—according to experts report, and equal to the finest in the world.

There are now three companies in the field, viz.; The Transvaal Asbestos Syndicate—now absorbed by the Consolidated Gold Fields; The South African Minerals Option Syndicate—a subsidy of the Bechuanaland Exploration

Company, and The Anglo-Swiss Asbestos Company. On one of the properties: that of the Consolidated Gold Fields, it is estimated that there are 150,000 tons of asbestos in sight. This property comprises the Diepgezet farm, in extent about 7,000 acres. Samples of the asbestos from this property were sent out to England and America, and the replies were received that a ready market existed for the class of material submitted. A 10 ton shipment of almost entire outcrop stuff was made to England, and £21 per long ton was realized. An offer was made for the better class of stuff from Germany at £40, and from England at £45 per long ton.

The South African Minerals Option Syndicate, owns the Victoria and Rietfontein farms, and on each of these asbestos has been discovered—in several places. The Anglo-Swiss Company are working near Goodverwaaht, and it is reported that the mine contains about 200,000 tons of asbestos of No. 1 quality. In view of the little work which has been done on the property, this statement cannot be taken seriously.

Latest reports from the Carolina fields[1] are less favourable. The Carolina Asbestos Company, which has an issued capital of £40,000, and owns the rights to all asbestos on the farm Diepgezet, No. 33 Carolina district, made a profit of only £20, during the twelve months ended September 30, 1908. Mr. Leslie Simson, the superintending engineer, is of the opinion that, considering the scarcity of native labour, the results obtained have been satisfactory. The asbestos at the end of the present workings is of good quality.

Mr. Graham Prentice—the manager, in the course of his report, shows that 673 feet of driving was done at a cost of 24s. 4d. per foot, or about 10s. per foot less than for that accomplished to the end of the previous year.

For every ton of asbestos recovered, 42 tons had to be mined; or 7½ tons more than previously. Altogether, 281 tons were recovered. The cost of 'cobbing' was £3 9s. 8d. per ton, compared with £5 15s. 0d. The term 'cobbing' is used to cover all operations in the process of recovering the asbestos from the containing rock. Sixty-two per cent of the asbestos recovered was over 1″ in length; for the last six months of the year, however, the asbestos over 1″ only averaged 40 per cent. The latter percentage is approximately what may be expected in future under the present conditions of working. The fluff obtained by sieving the free fibre out of the fines, constituted 14 per cent of the year's output; but 38 per cent of the output for the last three months of the year. The proportion of fluff is likely to increase; because the fibre in the stopes farthest in the hill comes away from the serpentine more readily than it did in the outside workings. A much larger proportion is set free when the rock is blasted down; which naturally increases the quantity of fibre in the fines, and decreases the quantity of lumps to be cobbed.

The *Mining Journal,* of London, October 30, 1909, has this to say regarding the Carolina Asbestos deposits:—

'It is understood that Messrs. Wernher, Beit and Co., of London, are having the Carolina asbestos deposits examined with a view to taking

[1] 'African World,' January 9, 1909.

PLATE LXI.

Asbestos reef in the Carolina district of the Transvaal. On the left, the mouth of a drive and the dump of waste rock.

PLATE LXII.

In the Carolina district of the Transvaal. Nearer view of the drive on the asbestos reef.

a hand in their development should the report be sufficiently encouraging. These deposits were discovered about five years ago, and although thin the quality is said to be such as to make them payable. The drawback hitherto seems to be that the companies working the deposits have not had sufficient capital at their command to turn the deposits to the best account, a fair amount finding its way to the dump through want of proper mechanical treatment. A short time ago it was understood that the "Carolina Asbestos Company," controlled by the "Consolidated Gold Fields," was about to introduce machinery for this purpose, but the proposal seems to have fallen through. The "Anglo-Swiss Company" having spent most of their capital on buildings, etc., and little on the mine, closed down some time ago, and the "Carolina Development Syndicate" followed suit about six months ago, after having, as they thought, done sufficient work to enable them to form a company to exploit the property on proper lines. Success did not seem to attend their efforts in this direction, but it is hoped that soon all the different asbestos mines in the "Carolina" district will be at work again.'

Natal.

In 1907 some asbestos discoveries at the Denny Dalton mine attracted some attention. It was stated at the time, that the width of the lode was between 6″ and 3′–6″; but that the quality extracted was not of the silky variety like that from Canada and Italy.

Rhodesia.

Occurrences of asbestos—discovered in 1908, are being opened in the Victoria district. A syndicate has just issued a report of operations from August of last year to the end of March, 1909; which shows that about 120 tons have been exported to England. In addition, there was mined about 100 tons of lower grade fibre, which has been stacked on the property, awaiting the time when it can be handled at a profit. It would seem from advices issued by the manager that not only can a monthly output of 30 tons of best grade fibre be maintained; but that a new quarry containing larger and richer material than that now being worked is about to be opened up.

The production for 1909 amounted to 550 tons, valued at £2,725.

Matabeleland. (Africa.)

A syndicate has been formed in London to work the Belingwe asbestos deposits. 1,500 feet of trenching has been done on a block of claims, with promising results.

India.

According to the *Indian Trade Journal,* several Marwaris of the Central Provinces are reported to be about to form a syndicate for the manufacture of asbestos goods. It appears that a mine exists near Kamptee, which requires development, and that the promoters of the syndicate are negotiating with certain Bengali scientists in Calcutta with a view to experiments being undertaken

with the raw material, which is believed to be of the very best quality. According to a recent geological report on the mineral products of India, asbestos is an Indian mineral which has not yet got beyond the prospecting stage, though attempts to work the product have been made in Merwara in Rajputana, Gariwal in the United Provinces, and the Hessan District of Mysore. According to Dr. Watt, asbestos is found in the Gokak Taluks in the Belgaum district in the Southern Mahratta country. It is also obtainable in quantities in the country to the south and west of the Kurrum river, Afghanistan.[1]

Japan.

A recent report from the Canadian Trade Commissioner says, that asbestos is produced at several places in Japan, especially in Kiushiu; but that the quality does not compare favorably with the production of foreign countries. The local production should perhaps be classed as a kind of serpentine. Although good material was once produced in Nagasaki in the Kiushiu district, the mine seems to be exhausted now. As the Japanese asbestos is not suitable for manufacturing purposes when taken alone, foreign material is imported for the purpose of mixing with the local product. It is difficult to get exact figures as they are not specified in the Customs' returns. Asbestos sheets, a manufactured article, were imported in 1907 to the amount of 428,671 pounds, valued at 41,843 yen ($20,921); Germany being the leading country of supply. Under the item 'Packing for Engines,' which contains a large quantity of asbestos, the value of imports for 1906 is given at 392,863 yen ($196,481), and for 1907 at 295,501 yen ($147,720). The principal customer for asbestos sheeting or packing is the navy; large manufacturing establishments also use it. There is an encouraging future for this business on account of the general expansion of the industries which use asbestos materials, and there will also be a good market for the raw material. The most important manufacturer of asbestos articles in Japan is the 'Japan Asbestos Company,' with headquarters at Osaka.

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[1] The writer has obtained a sample of the Indian asbestos. It is of a yellowish tint; and in appearance similar to the Italian asbestos; but has no tensile strength.

CHAPTER VIII.

COMMERCIAL APPLICATIONS OF ASBESTOS.

The manufacture of asbestos goods forms at present a very important industry, both in Europe and on the North American continent; and it appears that a stimulus was given in that direction through the discovery of asbestos in Canada. Up to 1878, goods manufactured of asbestos were few, owing to the difficulty of spinning. The only kind of asbestos of commercial value known at that time was the Italian variety. The manufacture of articles of merchandise, composed wholly or in part of asbestos fibre, is steadily increasing in both volume and in the number of manufacturers; and as it is being utilized in many of the luxurious appointments of modern life, since it is recognized as an important factor of safety, there can be no doubt that new uses will continue to be made, and that there will be a constantly growing demand for the mineral. According to Mr. Alfred Fisher—the General Manager of the United Asbestos Company, London—asbestos was first used in the United States in the year 1868-9, in connexion with the manufacture of roofing felt and cement; but it was reserved to some enterprising Scotchman to bring asbestos first to the notice of engineers in Great Britain. A Company was formed in the year 1871, called the Patent Asbestos Manufacturing Company, Limited: works were established in Glasgow, and operations commenced. Through the services of the priest Corona, the Marquis di Baviera, Signor Albonico, and Messrs. Furse Bros., of Rome, properties and concessions from the communal authorities to work asbestos in Italy, were obtained; and when, a few years later, another Company called the Italo-English Pure Asbestos Company, of London, came into existence, backed up by powerful influence: secured mining rights, and established a manufactory in Turin; keen competition for supremacy commenced. The result was, that in the year 1880 all these Companies were amalgamated by the formation of the United Asbestos Company, Limited, under the presidency of Sir James Allport, of the Midland railway.

The rapid progress made since the beginning of 1880, is seen from the consumption of the Canadian mineral, which increases every year. The extent to which certain asbestos goods were to become commercial necessities, was clearly demonstrated when the great fire occurred at the Iroquois Theatre, Chicago. All asbestos dealers and manufacturers were kept busy for a considerable time in filling orders for fireproof theatre curtains, and like material.

The application of asbestos seems to vary greatly in different countries. While in the United States large quantities of short fibre are used in the manufacture of pipe coverings of all descriptions; the European market principally calls for long fibre to be used for spinning, braiding, and weaving.

In giving a synopsis of what is generally known regarding the uses to which asbestos is now being applied, it must be remembered that any attempt to collect

reliable data is a difficult undertaking; arising out of the desire on the part of the manufacturers to keep everything secret in connexion with the bringing out of a new and useful article. For this reason the writer is not able to give absolutely reliable data; but on the more important points has endeavoured to obtain opinions from two or three different parties—where such was possible.

The principal application of asbestos pertains to the manufacture of millboard, paper covering, etc., and allied articles: a number of which are described in the following pages. Fully 65 per cent of the asbestos mill stock is utilized in the manufacture of these articles alone; but it will not be long before the asbestos slate or shingle business which is just commencing to be felt, will push its way more and more to the front. Indeed, it is not too much to say that the time is not far distant when fully 75 per cent of all asbestos produced in the world will be used in the manufacture of asbestos slates and shingles.

The asbestos slate business is only four years old; but during that short space of time, the demand for these articles has increased to such an extent that, factories for this purpose are being established all over the world.

Originally the invention of an Austrian, Mr. Ludwig Hatschek, of Bocklabrueck, Austria, it soon found its way into Hungary, France, Germany, Russia, Belgium, and the United States. The progress made in the manufacture of these articles has been astonishing. Hatschek's factory, at Bocklabrueck, alone, produced last year, 70,000,000 square feet. As already stated in the chapter on the 'Status of the Asbestos Industry,' the future expansion of the asbestos industry depends largely upon the manufacture of asbestos slate; for which greater quantities of mill fibre are required year after year. Indeed, Mr. Hatschek, perceiving the enormous quantities of cement used in his slate factories, has now established his own cement works in connexion with his asbestos works.

The outcry as to the decadence of the British asbestos industry is rather contradicted by the fact of the enormous strides the 'British Uralite Company' is making—despite foreign competition—in the production of their asbestos slate: which is a fireproof material. Their output is large, as instanced by 200,000 tiles having just been shipped to Argentina—to one order; and 70,000 feet to a West Indian port: this is quite independent of home consumption. They have so arranged their plant—which was supplied by a large engineering firm near London—to produce 1,000 tiles per hour, and this is hardly deemed sufficient for the orders in hand.

There are several asbestos slate factories in the United States; but only one factory, namely, that of Messrs. Keasbey and Mattison, of Ambler, Pa., which manufactures according to the 'Hatschek' formula and patents.

Already substitutes have been produced for asbestos. Hair or other organic fibres have been used in the manufacture of shingles. Experience has proved, however, that in every instance this organic matter decays, and produces spaces in the shingles, which renders them brittle, and lacking in homogeneity.

A further application which seems to increase every day is the manufacture of ornamental wall decorations; the longer fibres of asbestos are used for this purpose, and beautiful ornaments are made by a combination process, principally in France and Germany.

The manufacture of asbestos wood is one of the modern achievements in the application of asbestos fibre, and the firm of Johns Manville Company, of New York, have a special department for the purpose. It is used principally for electrical insulation, switchboards, fittings, etc.

Still shorter fibre is used in the manufacture of 'Alignum,' a new species of asbestos wool, used specially for window shutters, sashes, and doors.

Another application in which short fibre is used, is 'Asbestolit' flooring, which has been put down in several of the New York hotels, and which, apart from the beautiful finish it takes, seems to possess excellent qualities with regard to durability. The floor of the 'Old Astor House' is made entirely of this material.

In the manufacture of all these articles, namely 'Asbestos Wood,' 'Alignum' and 'Asbestolit,' a certain amount of cement is used with short asbestos fibre; and as the demand for these articles increases the asbestos mines of Canada, which as a general rule have always a surplus of short fibre on hand, will in the future have a good opportunity of disposing of large quantities of this material.

The question is often asked 'how much capital is invested in asbestos factories all over the world?' This, of course, is a difficult question to answer, owing to the unwillingness of the manufacturers to give reliable information on that subject; but from a general estimate it appears that outside of Japan not less than $60,000,000 are invested in asbestos manufacturing establishments.

Steam Packing.

The earliest modern application of asbestos to engineering purposes was in the manufacture of an improved gland packing. At first this was mostly in the form of mill-board; but the various modifications of this special manufacture, now in demand, are so many that it would be useless to attempt to enumerate more than the principal cases. As in the application of any other material, freedom from impurity is the essential quality in asbestos. When the manufacture of the packing was first commenced, it was frequently found that the fibres were more or less charged with minute particles of pyrites, magnetite, and other metallic impurities; which caused the piston-rods to be scored by the packing. The damage thus occasioned was at first erroneously attributed to the action of the asbestos itself rather than to the impurities contained in it. Immediately the real cause of this scoring or scratching was discovered it became necessary—in order to prevent it—not only to select the most suitable kind of asbestos for this special purpose; but also to thoroughly cleanse it from all gritty matter before spinning. In order to effectually accomplish this object, special machinery had to be designed. As soon as this was done, the yarn produced was pure, and capable of being woven into any kind of fabric. Another important point in the manufacture of asbestos packing is, that it shall not become hard in the gland. Whatever the material may be which is used for this purpose, it is a

matter of primary importance that, under the action of steam or heat, it shall retain its smooth, slippery condition; and its nature remain unaltered, however high the pressure or velocity of the steam to which it may be subjected. The characteristic qualities of asbestos admirably fit it for such purposes as these: its inherent lubricating property rendering it additionally valuable; since by its use a perfectly pure piston packing can now be produced, through which the rod slides with a minimum of friction. Other important features are: (1) that it does not require frequent renewing; (2) regularity in the motion of the piston is preserved; (3) all the machinery connected with it runs with perfect smoothness, and (4) its elastic nature keeps the joints tight longer than any other kind of packing.

Every manufacturer of asbestos goods has now his special asbestos packing; and as in these days of high speed ocean records, reliability is the supreme quality requisite in a packing, many devices have been invented to meet all the exigencies of modern requirements.

Metallic Asbestos Packing.

Owing to the modern use of higher steam pressures in manufacturing processes, the employment of asbestos packing has become a necessity; because packing made from organic substances burns out, and quickly becomes unreliable. Asbestos packing is, therefore, employed in nearly all high pressure plants, as well as very generally upon the war ships of the navies of the world, and the use of packings of this class is constantly increasing. Most of the various packings, in all the ordinary forms, are too well known to need description here; and metallic packings are used wherever such goods are required. These are made with a fine brass wire in the centre of every thread of asbestos in both warp and weft: the wire adding greatly to the strength of the cloth, while the wires themselves are completely protected. Hydraulic pipe made of the same material is of such a dense and close character as to be remarkably suitable for this class of work.

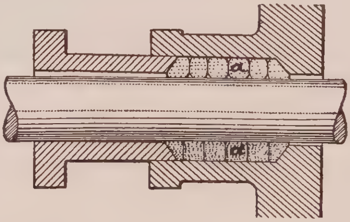

FIG. 52.—Asbestos packing in stuffing box of steam cylinder.

Asbestos piston-rod packing is composed of good long fibre asbestos, spun into strands and combined with a patented elastic core into any desired size; so as to form a compact and durable packing for locomotives, marine and stationary engines, valve stems, oil pumps, expansion joints, etc. It requires less oil than any other, being, to a great extent, self-lubricating, and, for this pur-

pose, will, it is claimed, outwear any other packing. It is easily applied, and is indestructible by acids, long exposure to dampness, or any degree of heat. Lubricating oils made from petroleum, work as well with asbestos packing as does either lard or sperm.

In the application for these purposes the heat resisting qualities of asbestos have been found to make it specially suitable for super-heated steam in the large triple and quadruple expansion engines used on fast ocean steamers. Asbestos packing has stood the test where all other packings—such as soapstone, flax, cotton, and even metallic packings have failed. It is durable, reliable, and economical: durable, in that it is not affected by the heat or moisture and less than other packings by friction and pressure; reliable, because it does not require to be frequently renewed, the regularity of motion in the piston is preserved, and as a consequence all the machinery connected with it runs more smoothly; and economical, for the reason that being to some extent self-lubricating a saving in oil is effected, and from its elasticity, caused by its fibrous nature, the joint is kept perfectly tight a longer time than with any other class of packing. The commonest form of asbestos packing is made by either twisting or braiding asbestos wick or yarn together into a rope; but a large number of other kinds of asbestos packings are on the market. Wire is sometimes used

FIG. 53.—Asbestos packing in joints of steam pipes.

to increase the durability and strength of the packing; while to increase the elasticity, an india-rubber core is sometimes inserted. To add to the lubricating property of asbestos packing, it is often manufactured with a filling of powdered soapstone or graphite. A very superior kind of asbestos packing consists of asbestos cloth rolled into any desired thickness, with rubber between the layers. In a similar manner, by uniting layers of asbestos cloth, a flat packing —generally called asbestos and rubber sheeting—is made, which can be cut into rings of any shape and form to serve as a superior flat joint packing, instead of mill-boards.

Asbestos tape made in a similar way as the sheeting, can be bent into the form of a ring and used for the same purpose as the sheeting; having the advantage of leaving no waste to the consumer. Such packings of combined asbestos and rubber are very much in use, owing to the advantage they have over the ordinary asbestos packing, in being more resistant to moisture and withstanding a still higher pressure. A so-called asbestos block packing is made by uniting a number of layers of asbestos cloth by means of india-rubber,

then placing a flat rubber back crossways at the edge of the layers and covering three sides by a cotton cloth, leaving one side of uncovered asbestos in contact with the piston rod. The rubber back increases the elasticity of the packing,

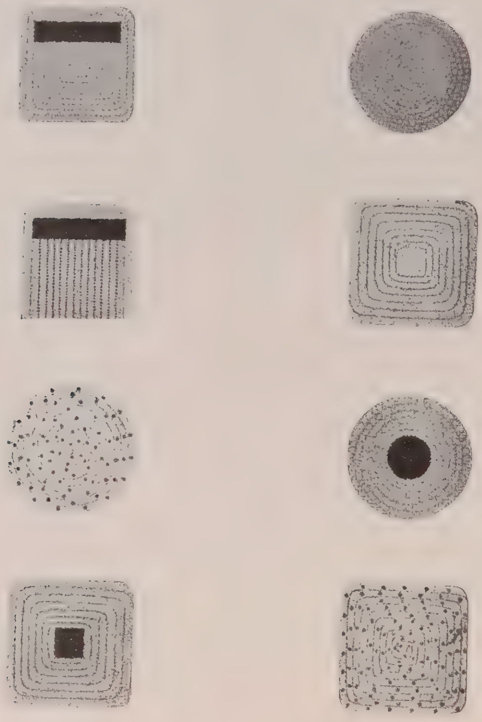

Fig. 54.—Various kinds of asbestos packing.

while the friction acts against the edges of a number of asbestos cloth layers. This packing has great power to withstand steam pressure.

There are a number of devices of steam packing used in stuffing boxes on the market. In one of these every asbestos thread has a core of fine wire, thus presenting a uniform surface of asbestos to the moving parts, rendering the packing suitable for wet or dry steam, and adding greatly to its strength and durability.

Asbestos Cloth.

Asbestos yarn, composed of pure asbestos fibre of the highest quality, is woven into cloth of varying construction, weight, and thickness, which, in turn, is made into safety drop curtains for theatres, amusement halls, and the like. About 1,000 of these curtains are made each year: the largest one in the world (at the Hippodrome, New York), as well as nearly all the others, being made of

asbestos fibre from Thetford Mines, which is well suited for this high class of work. Asbestos cloth is also used as a wall lining or covering in some theatres, where municipal regulations require it; while there is a strong inclination to use it for the production of theatrical scenery generally, as well as of curtains. An increasingly extensive use of cloth, mill-boards, asbestos building lumber, wood, etc., has recently sprung up, in the insulation against fire of the thousands of moving picture shows which are being introduced throughout all civilized countries. With the enactment of more stringent municipal ordinances, the employment of large additional quantities of asbestos will necessarily be required; since there is no material so practically suitable for this insulation, and for the protection of the public, as regards the preservation of both life and property, as asbestos.

Asbestos cloth is also coated with rubber, and used for the manufacture of gaskets, sheet packings, etc., its employment being greatly stimulated by the higher steam pressures which the use of steel boilers enables the manufacturer or steamship owner to risk. Under these conditions, nothing can replace asbestos, the use of which is necessarily in increasing demand because of the modern desire for speed—which is well-nigh universal.

Another field of use for asbestos cloth, which has immense possibilities, is, the employment of this cloth for the large mangles in hotels and steam laundries, as the constant dampness has no effect upon asbestos manufactures. The demand for this class of goods has never yet been supplied; due largely to the initial cost of installing the necessary machinery, and the anticipated difficulty of obtaining a regular and uniform supply of crude asbestos; so that a factory installed for the production of such asbestos cloths might be conducted without cessation.

Asbestos cloth is also coming into use in the automobile industry, and bids fair to become an important factor in the business. For this purpose, only the highest grades of Thetford Mines crude are employed; and this branch of the industry can scarcely succeed without this important and unique source of supply.

Asbestos cloth is used, however, in so many lines of trade and commerce, that it is difficult to do more than dilate upon the main uses to which this branch of asbestos manufacture is applied. Suffice to say that, new uses are being constantly found for this unique cloth, requiring all the crude asbestos produced by the existing quarries.

Concerning the spinning of asbestos it must be said that there are various difficulties to be overcome: (1) the fibre has not sufficient strength to withstand all the operations to which other fibres, of vegetable origin, such as flax, cotton, etc., or of animal origin, such as wool, silk, etc., have to be submitted. Moreover, a difficulty is found in preventing the asbestos fibres in the thread from slipping past each other.

While fibres like those of wool, flax, etc., have a rough surface, the surface of a single asbestos fibre is as smooth as that of glass threads; so that in trying to twist a number of single fibres together they slip. Continuous study of, and experimentation on, the nature of the asbestos fibre have to a certain extent

overcome these difficulties, and the manufacturers have succeeded in turning out a single asbestos thread, which, although not weighing more than an ounce per 100 yards, is of considerable strength.

It may not be out of place to mention, that investigations made by various municipalities in the United States regarding the safety drop curtains supposed to have been made of asbestos have shown that in many cases, very little asbestos was used in their construction, and that the materials employed were found to have been heavy jute, linen or cotton sheeting, or canvas.

Garments made of asbestos cloth are used as a protection against fire, and also against injuries from acids. As to the former application, while its adoption on account of the great expense involved is not likely to be effected for general use by fire departments; at least two men should be provided with asbestos suits, to enable them to enter burning buildings in case of necessity. These asbestos suits for firemen are provided with asbestos masks, which not only protect the face, but also the smoke respirators.

A complete asbestos fireman's suit consists of a pair of strong boots protected by an iron sole; asbestos trousers and gaiters, pocket, apron, gloves, mask, and head gear.

Several tests were made recently in London before a Commission at the instigation of the Association of London Dyers and Cleaners, who have constantly to guard against fire hazards of a very serious nature.

The objective of the tests is given as follows:—

To ascertain the effect of the application of asbestos cloths, sand, and steam, upon petrol and various burning materials; but principally upon burning petrol: and more particularly under conditions which would be met in processes employed on the premises of dyers and cleaners.

The following is a summary of the results of the tests by the Committee:—

The tests demonstrated the complete efficiency of asbestos cloths in putting out burning spirit vapour. In the case of burning materials it was demonstrated that asbestos cloths could be of use in confining fire until other appliances were brought into play.

Note.—The efficiency of sand was demonstrated where it can be employed to soak up spirit—the vapour of which is ignited.

The efficiency of steam, as applied, was demonstrated where a building in which the fire is burning can be closed up, so as to exclude as much draught as possible.

As to the lesson of the tests, Mr. Percy Collins, one of the members of the Commission, writing on the subject, says in his preamble:—

> 'The application of the asbestos cloths was certainly effective, and fully demonstrated their great utility in subduing fires caused by spirit vapour. They showed that where trade processes need the employment of a volatile spirit, these asbestos cloths form a most valuable first-aid appliance.'

Asbestos Rope and Yarn.

Fireproof asbestos ropes in use in fire departments are generally of two kinds: one entirely of asbestos, the other with a core of steel wire which greatly adds to its strength.

Tests have been made by the German government with Wertheims (Frankfort) wire-cored asbestos ropes, and it was found that a $\frac{3}{4}''$ asbestos rope with steel wire core, carried nearly 2,000 pounds; and then, only one of the seventy odd strands of which the rope consisted broke. These tests made by the German government are also interesting regarding the stretching of the asbestos ropes. With a weight of 100 kilograms attached, the $\frac{3}{4}''$ rope only stretched $\frac{3}{10}$ per cent; with a weight of 400 pounds it stretched less than 1 per cent.

The asbestos rope without the steel wire core is sufficiently strong for ordinary fireman's purposes. A $\frac{1}{2}''$ rope will carry fully 200 pounds; a $\frac{3}{4}''$ rope over 300 pounds, and 1″ rope is safe for 500 pounds.

The weight of these ropes runs as follows:—

$\frac{1}{2}''$ rope, weight about 10 pounds per 100 feet.
$\frac{3}{4}''$ rope, weight about 20 pounds per 100 feet.
1″ rope, weight about 40 pounds per 100 feet.
$1\frac{1}{4}''$ rope, weight about 70 pounds per 100 feet.

The wire core does not materially increase the weight.

The ropes are by no means heavy, are very strong, and can be conveniently used as life lines. They are not slippery, and are not injured by water.

Asbestos yarn is now a staple article in the manufacturing of asbestos goods. Messrs. Keasbey and Mattison, of Ambler, Pa., U.S.A., produce a pure asbestos yarn weighing all the way from 300 to 1,800 yards to the pound.

Asbestos Twine for laboratory work.—This is a strong, hard-finished, three-strand twine, about $\frac{1}{16}''$ diameter. It is fire and acid-proof, and its uses are similar to those of asbestos cord.

Asbestos Sewing Twine.—A very fine, strong, finished twine, used for sewing asbestos cloth, and for binding materials exposed to the action of fire or acids; also for philosophical and chemical apparatus. It is also adapted for insulating electric wires, etc.

Asbestos Incandescent Lamp Thread.—Composed of pure asbestos fibres, formed into a very fine thread, possessing a high degree of tensile strength, specially adapted for suspending incandescent lamp mantles, holding metals subjected to acid baths, etc.

Asbestos as an Insulating Material.

Non-heat-conducting coverings for application to steam pipes, boilers, and all heated surfaces, from which it is desired to prevent radiation, are manufactured to the extent of many millions of feet, each year. These are composed either entirely or in part of asbestos fibre, of varying degrees of quality. Magnesia coverings, it is true, are the accepted type of covering—commanding the highest degree of efficiency—yet even in the manufacture of these, from 10 to 15 per cent of long asbestos fibre is necessarily used as a binder; while on the other hand, non-heat-conducting asbestos coverings for steam pipes and boilers are manufactured, consisting of asbestos fibre alone. The coverings applied to

the steam piping underneath our modern railway sleeping and parlour cars—known technically as 'train-pipe' covering—are composed of pure asbestos fibre: and such coverings will doubtless continue to be employed while coal is burned.

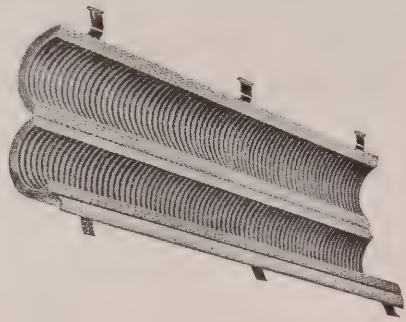

FIG. 55.—Asbestos air-cell steam pipe covering.

Asbestos is used in various ways for the purpose of preventing the radiation of heat from pipes, boilers, tanks, etc. As an insulating material, it is claimed to be superior to most of the other non-conducting materials: (1) because of its capability of resisting heat; and (2) because, being fibrous, it adheres better to smooth surfaces than do powdery substances. Numerous varieties of pipe and boiler coverings are on the market, and the large number of companies who make this class of manufacture a specialty is evidence of the commercial importance this article has attained in the United States.

The use of asbestos for felting purposes, runs through a large number of modifications. 'Fibre felts,' as they are technically styled, are composed of pure asbestos fibre, and are used in large quantities for insulating the heat radiating surfaces of automobiles, particularly the steam driven motor cars; while the felts are very generally employed for wrapping around small pipes; the insulation of electric service wires; and the manufacture of sad iron holders, etc.

Experiments have long shown the great economy effected by covering steam pipes. The waste of heat in using 100 feet of 2″ pipe uncovered for the conveyance of steam from 70 to 80 pounds pressure, for one year of 3,000 working hours, costs $16, with coal at $2 per ton. But by using the least efficient of insulating coverings this loss is reduced to about one-fourth of that amount, and with the best procurable to about $2.50 per year. Other experiments have shown that the loss incurred by using uncovered or inefficiently covered steam pipes is considerably more, and probably the truth lies between the two; for a steam pipe is usually under pressure for more than ten hours a day, and coal cannot always be had for so low a price as that mentioned.

A square foot of uncovered pipe, filled with steam at 100 pounds pressure, will radiate and dissipate in one year the heat put into 3,716 pounds of steam by the economic combustion of 398 pounds of coal. Thus, 10 square feet of bare pipe corresponds approximately to the waste of two tons of coal per annum.

To sum up: pipe and boiler coverings prevent radiation of heat and consequent condensation of steam.

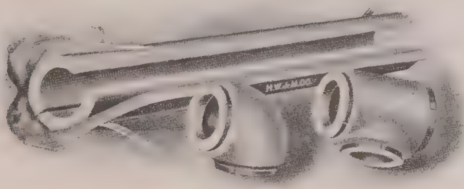

FIG. 56.—Asbestos magnesia pipe covering.

This means: (1) Saving in cost of fuel.
(2) Increase of power and general efficiency.
(3) Reduced temperature and greater comfort in surrounding atmosphere.

In fact, more satisfactory results from any steam plant.

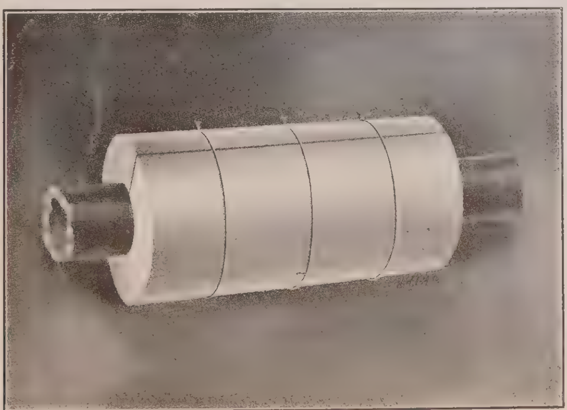

FIG. 57.—Asbestos magnesia pipe covering.

Further, it must be remembered that the loss by radiation varies according to the surface exposed, and the difference in temperature between the two bodies. The condensation which takes place in a steam pipe has two very serious features: (1) if it be carried into the cylinder, a serious breakdown may result; and (2) it must be borne in mind that only about one-tenth of the heat energy in the steam is available for producing power, consequently every unit lost by radiation from a steam pipe leading to an engine, means the loss of ten times as much heat from the coal burnt. This may appear enormous, but it is nevertheless true, and even much more so in the case of the commoner type of engines; because in these, the available part of the heat is often not over one-

twentieth part of the whole. In such cases it is no uncommon thing to find one-half of the coal thrown away, by allowing the boilers and steam pipes to remain unprotected.

A very practical test to ascertain the loss of heat from uncovered steam pipes and those covered with asbestos coverings was conducted by L. A. Upson, Superintendent, and Chief Engineer Steele, of the Hartford Carpet Company, with the following results:—

A room having a very even temperature and free from draughts or air currents was selected, close to the boilers, where steam could be taken from the top of the main pipe, and free from water of condensation.

A suitable vessel connected to 120 running feet of 2″ steam pipe was arranged to collect the water of condensation. A short section of the pipe was enclosed in a suitable box, with a glass in the side for the purpose of reading the rise in temperature, as indicated by a thermometer placed therein.

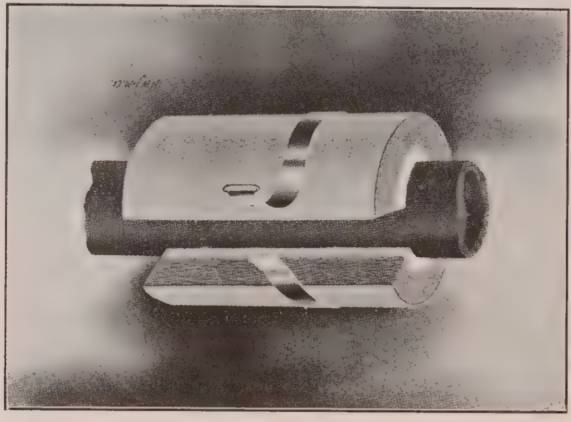

FIG. 58.—Asbestos felt covering.

Steam was first blown through the pipe and receiver, until both were free from the water of condensation; which was caused by heating the pipe and receiver. The valve was then closed, 10 hour trials were made, and the water carefully collected and weighed—with the following results:—

—	No. 1.	No. 2.	No. 3
Average steam-pressure	79	77	80 pounds
Average temperature of room	70	69	70 degrees
Average temperature of box	167	80	107 degrees
Water condensed	862	222	480 pounds

Each trial as given above, was for 10 hours: 120 feet of 2″ pipe; No. 1 pipe uncovered; No. 2 pipe covered with asbestos; No. 3 pipe covered with plastic material.

It will be seen from the above, that the loss by radiation greatly exceeds that usually estimated for uncovered pipes; but it agrees very well with the trials made upon machines carrying high steam pressures. The saving by covering the pipes is very satisfactory, and in the second trial the temperature in the enclosed box was but little higher than that of the room.

On the accompanying chart (Fig. 59) the radiation has been taken as 2·75 B.T.U., per square foot of heating surface of bare pipe per hour, for each Fahrenheit degree of difference between the temperature of the steam in the pipe

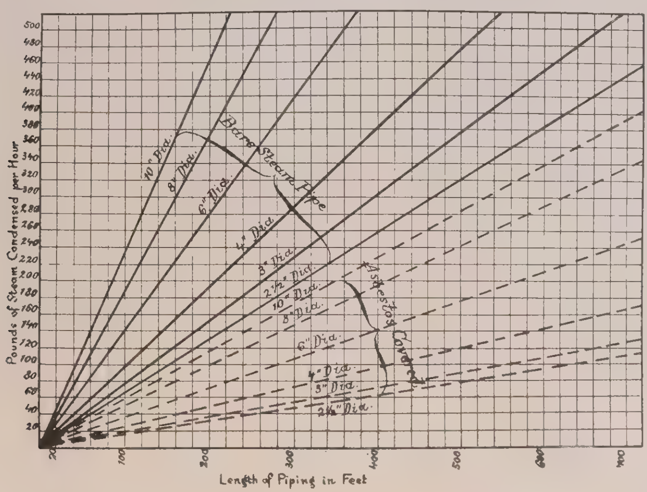

CHART FOR CALCULATING DIFFERENCE IN LOSS BETWEEN BARE AND ASBESTOS COVERED PIPE

Note: Condensation in Asbestos Covered Steam Pipe thus: - - - - -
" " Bare " " " ———

FIG. 59.

and that of the air outside it.[1] This figure is probably a minimum: it particularly refers to pressures of less than 100 pounds, and has been arrived at after considering available data. A steam gauge pressure of 100 pounds and an average air pressure of 77° F have been taken.

The equivalent condensation per square foot of bare pipe per hour=0·82 pound of steam arrived at as follows: steam gauge pressure, 100 pounds per square inch; temperature of steam at above pressures, 338° F; average temperature of air, 77° F; difference, 261° F; loss per square foot per hour =261×2·75=717 B.T.U.

[1] Abstract of an article by W. R. Degenhardt in the 'Monthly Journal' of the Chamber of Mines of Western Australia, June 30, 1909.

To change one pound of water at a temperature of 338° F, into steam at 338° F requires 877 B.T.U. Therefore, the loss by condensation per square foot of bare pipe per hour is $\frac{717}{877}=0{\cdot}82$ pound. This result forms the basis for constructing the full line plottings in the chart.

With asbestos-covered steam pipes the loss by condensation may be taken as one-fourth that of a similar uncovered surface, and it is on this basis that the dotted line plottings have been made.

By taking any of the sizes of steam pipe indicated, and following the ordinates for length to the corresponding abscissæ for pounds of steam lost per hour, the difference in loss between bare and asbestos-covered piping can readily be perceived. The plottings can be taken only as approximate; but should serve to indicate in any particular line of steam piping, whether a closer investigation would be justified.

The common way of preventing the radiation of heat from pipes, boilers, etc., is, to mix loose asbestos fibre, after freeing it fairly well from stone admixtures, with other materials which either serve to increase the non-conducting qualities of asbestos or to make the composition adhere better to the surface of the pipes. Such a mixture made into a uniform paste with water, is laid on smoothly by means of a trowel as a thin covering around the pipe. Several layers are usually put on, allowing each to dry thoroughly before the next is applied. To finish off, canvas or oil-cloth is used, which prevents the covering from falling off, should it become cracked in the course of time.

The Canadian Asbestos Company manufactures an asbestos cement composed of 90 per cent of asbestos fibre: which forms a light porous covering, partaking of the nature of a felt and cement, and is applied while heated to the boiler or pipe surfaces.

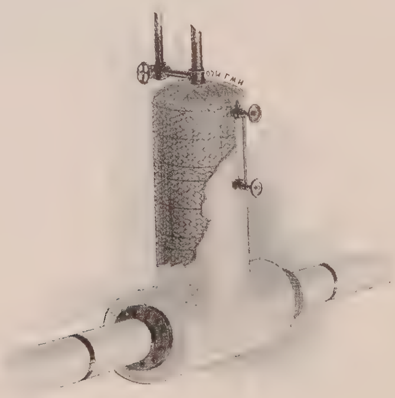

FIG. 60.—Asbestos cement applied to steam pipes.

Another mode for using asbestos for covering pipes is effected by forming it into sectional pieces, which are placed on the pipes and connected by means of

iron bands or canvas (Fig. 58). This mode of applying asbestos has the unique advantage not only of being easily put on and taken off the pipes; but the same covering may be used for a considerable length of time. Special sectional pieces of such covering are made to fit elbows, tees, crosses, and other fittings.

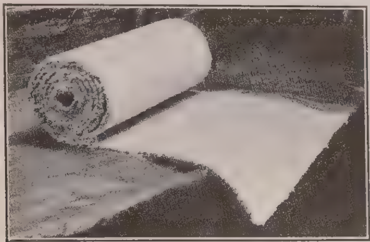

FIG. 61.—Asbestos felt.

The sectional pipe covering, as illustrated in Fig. 60, is composed of a moulded asbestos core ½″ thick, and ½″ of corrugated wool felt; which binds the moulded portion, making it tough and durable. This form of construction makes an excellent non-conductor.

On larger surfaces it is better to cut from a sheet of 1″ fine felt, sufficient to cover the iron, and after wiring the same, to partly finish with asbestos cement in two coats. (Fig. 63).

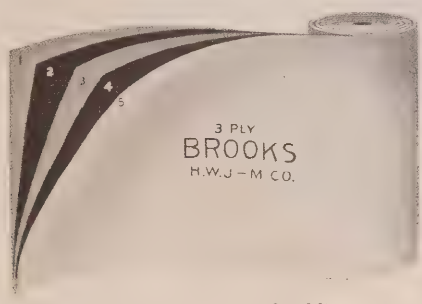

FIG. 62.—Asbestos roofing felt

Removable Boiler Covering.

Throughout the non-civilized world, where the locomotive penetrates as the advancé guard of civilization, these engines must be protected from loss of heat and the excessive consumption of coal or wood. This is done by blanketing the engine with asbestos mattresses: firm, light structures, made of asbestos cloth, and stuffed with asbestos fibres; since such clothing is tough and firm, may be easily handled, removed for repairs to stay bolts, crown sheets, etc., and re-applied by unskilled labour, without injury to the fabric. In India, and throughout the East generally, all locomotives are covered with mattresses or

'clothing' as it is called, consisting wholly of asbestos. In the United States and Canada, as well as in Great Britain, some 75,000 locomotives are now in service, covered with 'Magnesia Laggings,' 15 per cent of which consists of long asbestos fibre.

The Asbestos Covering, manufactured by the Johns Manville Company, of New York, is made of successive layers of plain and corrugated asbestos felt, which, on account of the numerous air cells thus produced, effectually prevents radiation (Fig. 65).

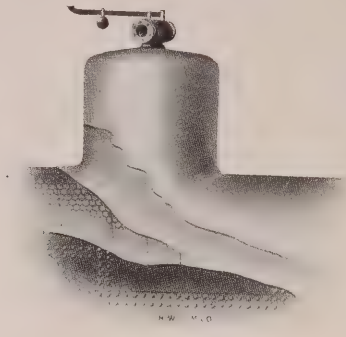

Fig. 63.—Asbestos cement applied on boilers.

Asbestos Cement Felting.—This felting is composed of asbestos fibre, infusorial earth, and a cementing compound. It is applied with a trowel to steam pipes, boilers, etc., while heated. (Fig. 64.)

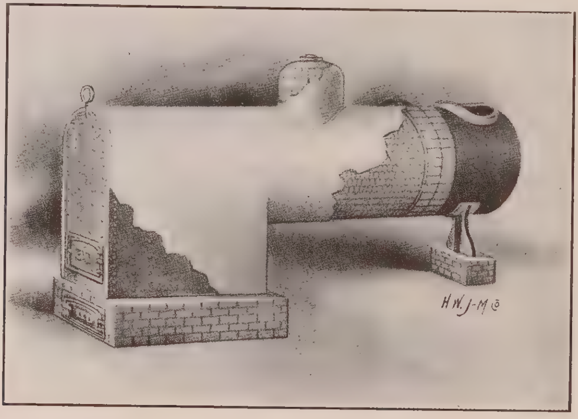

Fig. 64.—Asbestos cement applied on boilers.

The expansion and contraction of large sheet metal surfaces are often so great as to injure pure cement coverings. In placing asbestos felt sheets next to the iron, however, this difficulty is entirely overcome. For pressures of 125

pounds and upwards, the following covering is recommended by the Johns Manville Company: first, next to the iron, place 2″ asbestos felt sheeting, wire the same on, then cover with mesh wire and finish with ½″ coat of cement.

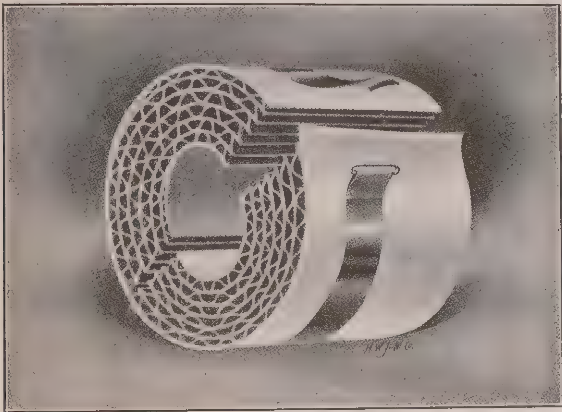

Fig. 65.—Asbestos air-cell covering.

Asbestos Mattresses.—The subject of covering steam boilers and pipes in Great Britain has been brought into special prominence by the rule of the Board of Trade, in London, to the effect that all steam pipes and boilers of marine engines shall be tested at certain intervals by hydraulic pressure, to double the working pressure. Before testing the pipes and boilers, the cover must be removed. This rule points to the desirability of producing satisfactory removable boiler and pipe covering. The idea of making quilts or mattresses composed of asbestos cloth filled or stuffed with non-conducting material is not new; for this was done in London as early as 1885. But the way in which these quilts or mattresses were prepared was somewhat defective, as the fibre or other material with which they were filled shifted its position; the result being, that

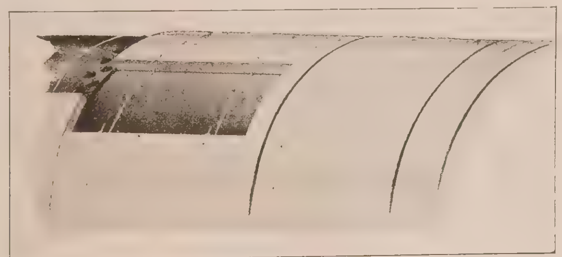

Fig. 66.—Asbestos wired mattress for covering boilers, etc.

some parts of the mattress became choked, and other parts empty. All these defects have been removed, and the mattresses as they are now made—especially

for modern warships—are effective and durable. The weight of this covering is only $1\frac{1}{2}$ pounds to the square foot: is easily applied, and may be removed and replaced without trouble.

It is made in blocks of standard size $6'' \times 36''$, and $1''$ thick, upwards. The method of application is very simple, as can be seen by reference to Fig. 66. Wires are passed around the boiler at about $4''$ from the ends of every course of blocks. A special T-hook or fastening engages the wires, and the blocks are slipped under the hook, which holds them firmly in place. This method of fastening permits the removal, when necessary, of a single block, without disturbing the others.

Asbestos Mill-board.

Manufactured into mill-board, asbestos finds a variety of uses. The mill-board serves as a joint packing for steam pipes, cylinder covers, steam chest covers, etc., and is greatly appreciated for its durability, economy, and cleanliness. It will adapt itself to uneven surfaces and forms a perfectly tight joint, which, with very little care, can be removed and replaced without injury. For special purposes—especially when there is much water in the steam pipes—asbestos mill-board can, by special treatment, be made perfectly waterproof. Asbestos mill-board is also used for other purposes, such as th construction of fireproof deed boxes, etc. (Fig. 67).

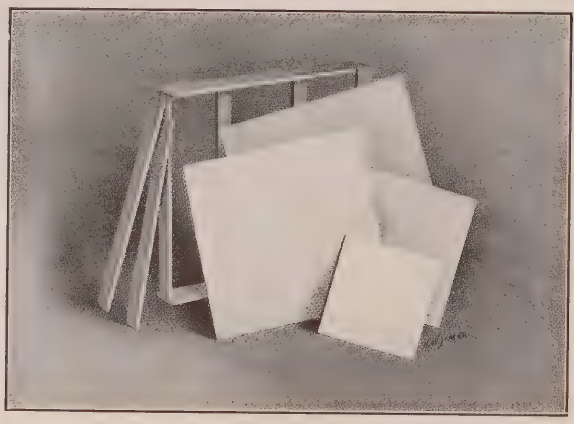

Fig. 67.—Asbestos mill-board.

The manufacture of asbestos mill-board is somewhat similar to that of ordinary cardboard. In the works of the United Asbestos Company, London, the asbestos fibre, after some preliminary treatment, is run with water into the tanks of beating engines. Each of these tanks is provided with a rotating beater, which maintains a thorough circulation, taking up the fibre, opening and drawing it out, and then sending it forward to be soaked for a time until it comes round again to the beater. The binding ingredients are here added and

thoroughly mixed with the fibre, when the pulp is passed into the vat of the mill-board or paper machine; where it is kept in a state of agitation until gradually drawn off. The water passes through a fine wire gauze on a revolving cylinder, leaving a thin coating of pulp on the cylinder. This is then transferred by means of an endless band to a second rotating cylinder, where it gradually accumulates until the desired thickness has been reached. It is finally cut across and removed in the form of a square sheet of mill-board. As the sheets contain a large percentage of moisture, they are next placed between sheets of zinc and passed under hydraulic pressure, then hung in drying rooms, where the final pressure is applied, the edges trimmed, and they are then ready for the market.

In this process the chemical composition of the asbestos undergoes little if any change, and with the exception of the binding materials which have been added, chemical analysis shows the composition of the best mill-boards to be practically the same as the fibre from which they are made. It will be observed that nothing would be easier than to adulterate mill-board pulp while in the beating engines, and as a matter of fact large quantities of china-clay, and other ingredients, are used by some manufacturers in this process. It has the effect, not only of increasing the weight, but also of reducing the cost, to the detriment, however, of the finished article.

A patent has been granted to T. H. Ibbotson, East Greenwich; and R. Meldrum, Blackheath, England, covering a process for the manufacture of mill-board asbestos fibre.[1] The main features of this patented article are as follows:—

Asbestos of $\frac{1}{8}''$ to $2''$ long (100 pounds) is thoroughly mixed in a beating machine with a magnesium chloride solution, having a specific gravity 1·25 to 1·5 (250 to 500 gallons). Finely divided magnesium oxide (50 to 150 pounds), which should weigh at least 25 pounds to the bushel, is then added, and the mixing continued. The pulp obtained is filtered, and the comparatively dry residue left on the filter-bed is subjected in a hydraulic press to a pressure of 200 to 300 pounds per square inch, and allowed to dry in the air. The hard slabs obtained are next washed with water, to remove soluble salts, then immersed in a 20 per cent sodium or potassium silicate solution, and subsequently immersed for fifteen minutes in a magnesium chloride solution. They are then aid dried, and afterwards treated with the silicate solution.

The process described in the United States Patent 694,859[2] is improved by thoroughly incorporating fibrous asbestos and powdered sulphur into a pulp with water, and forming the pulp into paper, mill-board, or other convenient article. The water is then removed, and the dried product saturated with a suitable oil. The material is subsequently subjected to a vulcanizing process by the carefully regulated action of heat, a temperature of about 300° F being maintained for a definite time.

Asbestos mill-boards are used in enormous quantities in the stove and range industry: all modern ranges having their oven doors lined with this material.

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[1] Chemical Industry, 1903, page 1,088.
[2] Journal Society of Chemical Industry, 1906, Vol. 2, page 1,069.

They are also used as flat packings for steam pipe joints and gaskets, also in many other departments of modern industry.

Asbestos Writing Paper.

The manufacture of paper from asbestos has met with many difficulties owing to the natural affinity of asbestos for water. Only a few kinds of asbestos are suited for the production of a good paper and then special treatment of the fibre is necessary. Most of the paper made contains only about one-third of its weight of asbestos. It is reported that a good class of asbestos paper was at one time made in Paris; but the principal defect of all asbestos papers is the natural tendency to work up more like blotting paper than ordinary writing paper. It is difficult to obtain a glassy surface of the paper to enable the pen to glide smoothly over it and prevent the ink from running. An invention to remedy this defect would certainly tend to stimulate the manufacture of asbestos paper. Much has been accomplished in this direction; but still, even the best writing paper produced is too tender, and although itself fireproof, the writing upon it does not withstand a red heat.

Lining of Furnaces.

Inasmuch as asbestos is one of the most refractory substances known, it is advantageously used in a variety of ways for the lining of furnaces. When the metal and fire are together—as in the cupola, or blast furnace—it constitutes a most enduring and heat-confining lining, and is particularly adapted for use where the metals or ores contain sulphides, as sulphides have no effect on asbestos.[1] As linings for furnaces and kilns, and for use in the manufacture of crucibles, a patent has been granted for an improved refractory material composed of a mixture of the aluminous asbestos from Natal with fireclay: in the proportion of one part of asbestos to four of fireclay. Both are finely pulverized, and formed into the desired shapes while in a plastic state. The patentee states that if a material of greater fire-resisting properties is required, the worn out 'saggers' are pulverized and a fresh supply of fireclay, equal to double the amount of powder 'sagger' is added. When this material is exposed to extraordinary heat it does not crack; but, on the other hand, tends to fuse and bind its particles closer together. Another convenient property of the material is, that it is capable of resisting the attacks of atmospheric and chemical substances, such as damp, sewage, etc. This special form of asbestos is stated to be additionally valuable both on account of its cheapness and the convenient form in which it is imported.

Firebrick.—The Canadian Asbestos Company manufacture a firebrick which is pronounced to be a perfect substitute for and a great improvement on, the conventional fireclay brick. It is intended for lining and relining all styles of cooking stoves, ranges, heaters, etc. It is also invaluable for lining doors of boilers, furnaces, and setting up firebrick in stone walls, etc.

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[1] Jones, 'Asbestos,' page 218

It has many advantages over ordinary firebrick: (1) it costs less; (2) it is always ready for use; (3) conforms to irregular surfaces; (4) can be easily applied; (5) does not burn out, and (6) clinkers will not adhere to it.

Asbestos has been used in the manufacture of fireproof bricks, and tests made by the British Fire Prevention Committee (Stone, February, 1901) on gypsine, a fireproof material composed of hydraulic lime, sand, and asbestos pressed into bricks, showed remarkably good results. One side of a 9″ partition of gypsine bricks, set in hydraulic mortar, and lightly coated with a layer of fireclay, was submitted for an hour to a temperature which reached 2,050 F. The material was in no way affected, and the temperature of the outer surface was never sufficiently high to ignite a match held against it.

Asbestos, in its fibrous form, or in a finely divided state, is filled with an extraordinary number of air-cells, and for this reason contains in itself every requisite for a perfect non-conducting covering; by using it in this way, therefore, in its pure and fibrous form, without any admixture of foreign material, the most satisfactory results are obtained.

Asbestos as a Building Material.

The trend of modern architectural and municipal thought is in the direction of fireproofing, and the utilization of fire retarding materials generally, in the erection of buildings. In this type of construction, asbestos plays an ever increasing part. About 30,000 tons of asbestos paper are used in building construction alone each year; and a proper regard for the protection of life, upon the part of municipal authorities, would result in the sale of at least 100,000 tons per annum, in the principal cities of the United States, alone.

Asbestos is a natural heat insulator; and its silky fibres are capable of manipulation into any form. It is unaffected by extreme weather conditions; is absolutely fireproof, and is only moderate in cost. Commencing at the very foundation of modern buildings, asbestos and its by-products enter largely into their construction; and are used throughout: exterior and interior—even as a roof covering. Various new lines of building materials have been introduced into the trade, the chief constituent of which is asbestos. After the first-floor joists of a modern residence are put in place, asbestos plaster can be used in conjunction with either wood or metal lathing as a 'scratch' coat on the ceiling of the cellar. Thus used, it offers a positive fire barrier between floors, hence is the most satisfactory form of plastering known.

Between all floors, and between the outside boarding and clapboards, the use of asbestos sheeting papers and sheeting quilts has met with universal success. These have many advantages over other products, owing to their natural fire-resisting properties. They not only prevent the transmission of sound waves between rooms, but will effect a considerable saving in fuel when placed upon the side walls of wooden structures. Similar felts are also used on roofs, under shingles and slates, and ensure a comfortable building throughout the entire year.

Two asbestos specialties recently introduced on the market are, 'Transite' and 'Electrobestos'; manufactured by the Johns Manville Company of New York.

Transite is a dense, smooth, rigid mass of asbestos fibre, compressed into sheets, mouldings, and panels of various thicknesses from $\frac{1}{8}''$ to $\frac{3}{4}''$, and ranging in standard sizes up to 3′–6″ × 7 feet. It can be sawed, chiselled, planed,

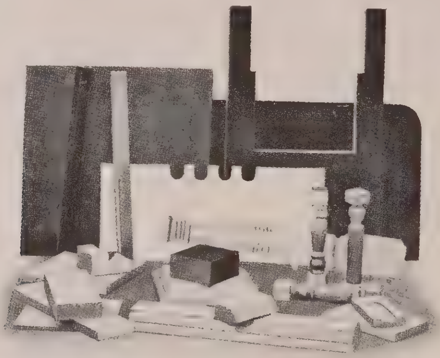

FIG. 68.—Asbestos wood-graining and finishing.

and machine-tooled; will hold screws, and can be handled like wood in every particular; but is, of course, absolutely incombustible. It can be stained, painted, and decorated, has strong wearing qualities, and is superior to metal in many applications, as it is not affected by acids, gases, or weather.

Electrobestos is an agglutinated mixture of asbestos and non-conducting materials; which can be moulded into all shapes required by the electrical industry. It possesses to a high degree the qualities of incombustibility, non-conductivity, and non-absorption of moisture, and is being extensively used in connexion with electric lighting, the heating of buildings, and in street cars.

A recent United States Patent (No. 769,087) issued to T. H. Ibotson and R. Meldrum, of England, covers a process of making asbestos boards. Asbestos fibre is made into a pulp with magnesia, and the mixture is treated with an alkaline-silicate solution before being pressed into shape.

Asbestos building lumber, asbestos wood, asbestos boards, and similar manufactured articles, are employed to a large extent in the protection of electric short circuiting of trolley or electric cars; for fireproofing, and for general protective purposes. When these asbestos products are saturated with asphalt compounds, they become useful for general electric uses: cut-outs, switchboards, etc.

One of the largest uses in the future, for asbestos fibre generally, will be its employment in the manufacture of asbestos roofing slates: hundreds of millions of which have already been made, and which promises to be the largest future use for clean, short fibre. The present demand for asbestos fibre in the manufacture of these slates, amounts to about 10,000 tons per year; and the

Thetford building covered with asbestos slate.

demand for asbestos fibre for this particular purpose is increasing daily. It ought to be five times as great, and there is little doubt that in the course of

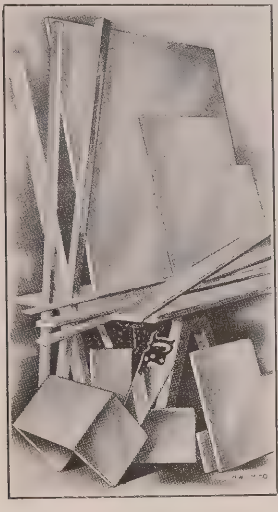

FIG. 69.—Asbestos wood for building construction.

time, the demand will be greatly increased. A Canadian factory for the manufacture of asbestos slates has just been equipped at Lachine, Que., drawing all its asbestos supply from Thetford Mines and Black Lake.

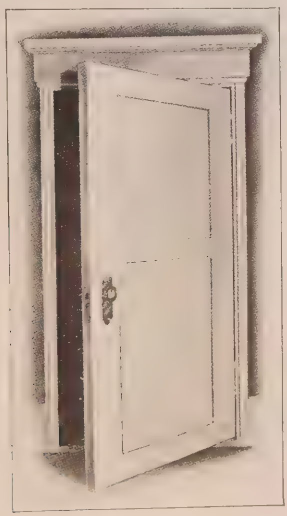

FIG. 70.—Door and door frame made of asbestos wood.

ASBESTOS CEMENT SLATE.

This is practically indestructible by atmospheric influences, so that maintenance expenses for roofs covered with this material are excluded.

For a period of three months the asbestos cement slate absorbs, and assimilates moisture in exactly the same ratio as the best natural slate. After that time the absorption ceases altogether, and the material becomes impervious, indestructible, and as hard as iron. The stringy asbestos fibres, which, by the characteristic peculiarity of a patented process, are embedded cross-wise in the cement paste, have exactly the same effect as concrete-steel constructions. They impart to the asbestos slate extremely high physical strength, indifference to blow and shock, and great elasticity; which properties are of the same importance to conveyance, and the laying of the asbestos slates, as they are to their durability and length of service.

The insulating capability of asbestos when brought to bear either upon heat or cold, imparts an increased importance to asbestos cement slate, not only in

FIG. 71.—Freight sheds of the Boston and Maine railway, Boston, Mass. (Covered with asbestos slates.)

its suitability for the tropics—where it is commonly used as a substitute for corrugated iron; but also for the continental climate, where it is economically used in workshops, in dwelling rooms, and particularly in garrets, which, with other roof coverings, would have to remain unoccupied.

The fireproof quality of asbestos renders asbestos cement slate a thoroughly fireproof material, which, owing to its strictly scientific manufacture, can not become either cracked, rent, or scaled in case of fire.

A series of tests were made with asbestos and magnesia building lumber by Mr. George Sever, New York.[1] This material was manufactured by Keasbey and Mattison, of Ambler, Pa., for whom the tests were made.

[1] United States Mineral Resources, 1904, pages 1,125-1,136.

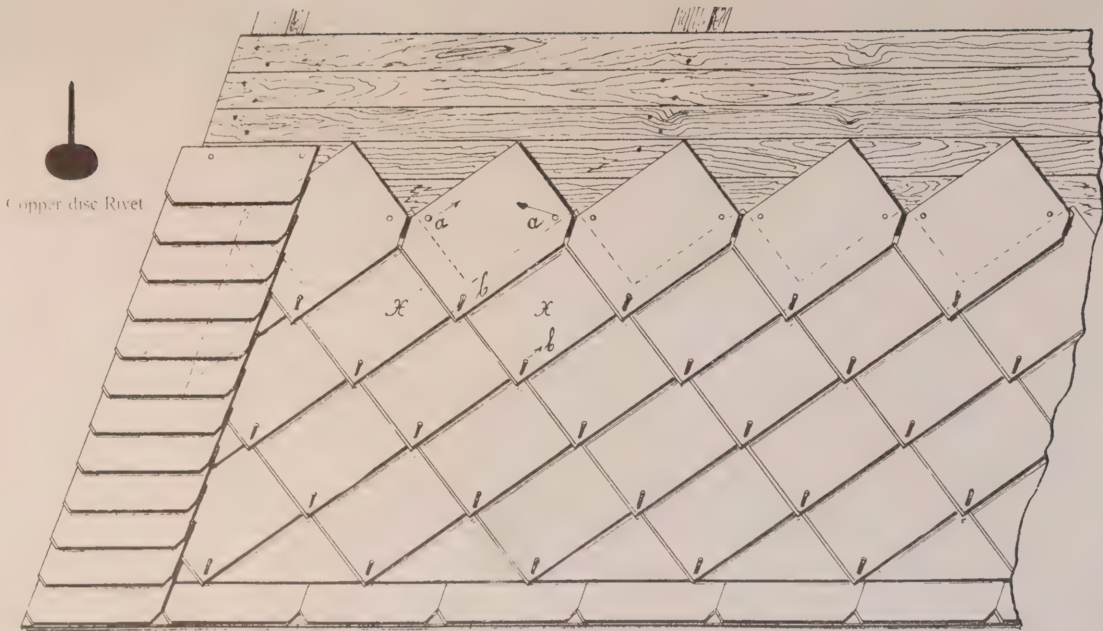

FIG. 72. Arrangement of asbestos slates on roof.

The first two tests demonstrated that as regards electrical resistance, magnesia board as an insulating material is a little more satisfactory than asbestos board. In the third test the material was subjected to the heat of an arc lamp of 500 watts for 20 seconds. The magnesia board seemed to stand the test better than the one made of the asbestos; because the face of the latter was considerably affected, the strength of the fibres having been destroyed.

In the following test—No. 4, asbestos showed itself to be a far superior non-conductor of heat than magnesia. The boards were held $\frac{1}{2}''$ away from the centre of the $\frac{7}{16}''$ upright carbons of an arc lamp, and a piece of white tissue paper was placed on the side of the material away from the arc lamp.

Fig. 73.—Residence covered with asbestos slate.

In test No. 5, it was shown that asbestos board withstands heavy blows better than magnesia board. These vibratory strength tests were made by nailing pieces of asbestos and magnesia board firmly to a wooden base, and then noting the effect of blows from a two-pound hammer, delivered at the rate of 70 blows per minute, on the mass of the material:—

VIBRATORY TESTS ON ASBESTOS AND MAGNESIA LUMBER.

Specimen No.	Material.	Average Thickness.	Effect of Blows.
		Inches.	
1	Asbestos....	0·2770	Slight indentation only, did not loosen about nails.
3	"	0·2818	" " "
9	"	0·1548	Slight indentation only; loosened slightly about holes.
11	"	0·1576	" " "
17	"	0·5185	No effect.
19	"	0·5207	"
37	Magnesia...	0·2550	$\frac{1}{16}''$ indentation, material shows signs of splitting.
39	"	0·2520	$\frac{1}{32}''$ indentation, material shows signs of splitting.
45	"	0·1130	$\frac{1}{32}''$ indentation, loose about nails.
47	"	0·1120	" " "
25	"	0·4910	$\frac{3}{32}''$ indentation, decided tendency to split shown on edge of sample.
27	"	0·4972	$\frac{1}{16}''$ indentation, material split on edge.

No. 6 showed that asbestos is better adapted for use in damp places than magnesia. These tests were carried out first by thoroughly drying the specimens,

and then thoroughly soaking them in water: first for 4 hours, and finally for 48 hours. The results obtained, demonstrated conclusively that magnesia will absorb a considerably larger percentage of water than asbestos.

In test No. 7 it was determined what resistance both magnesia and asbestos board offered to sawing and nailing. The results show that there is little tendency in the asbestos board to split; while magnesia is liable to split if subjected to a series of blows, or if a sudden shock occurs too near the edge of the board.

Professor Sever came to the conclusion that in all experiments, asbestos lumber possesses more mechanical properties than magnesia; but that magnesia is a better electrical insulator than asbestos. The latter possesses better heat resisting qualities, and in this respect asbestos board appears to be far superior to magnesia.

Quite a number of important investigations and tests were made in American universities and industrial institutions; and Mr. Hyde Pratt[1] reports on these as follows:—

> 'Additional tests were made upon asbestos mill-board, respectively one-eighth, one-fourth and one-half inch in thickness, by Mr. Ira H. Woolson, in the Mechanical Engineering Testing Laboratory, of Columbia University.
>
> 'One test was by heating the samples first at a low temperature and then gradually raising the temperature until the samples came to a bright red heat. Another test was by placing samples of the asbestos board over a furnace with the temperature maintained at 1,700° F, and leaving them for various lengths of time. Still other samples were heated red hot and then plunged under a strong stream of cold water. The results of these tests on the three thicknesses of board were practically the same, with the exception that the thicker the specimen the longer the time it required to attain the same degree of heat. In all cases the material contracted on the side next to the fire, which caused it to warp or curve with the concave side next to the heat. This curving was quite marked and sometimes amounted to as much as $\frac{1}{2}''$ in the specimens of the $\frac{1}{8}''$ board, and the deformation was permanent, practically none of it being removed by cooling. This curvature was not half as much in the $\frac{1}{4}''$ board, and in the $\frac{1}{2}''$ board it was only about one-fifth of what it was in the $\frac{1}{8}''$ board. These experiments show, as had been demonstrated before, that a high degree of heat will cause the asbestos fibres to become brittle, although it does not destroy their heat resisting properties.
>
> 'This brittleness produced in the chrysotile-asbestos has not unlikely been caused by the change in the molecular structure of the asbestos due to loss of water. Chrysotile-asbestos is chemically a hydrous magnesium silicate represented by the formula $H_4Mg_3Si_2O_9$, or $2H_2O$ $3MgO$ $2SiO_2$. At a high temperature the two parts of water (H_2O) that the chrysotile-asbestos contains would be readily driven off, leaving a compound composed of magnesia and silica. This change in the chemical composition of the material would change to some extent at least its physical character, and it is probable that it is the direct cause of the loss of strength of the fibres. The subjecting of the red hot asbestos board to cold water did not seem to have any special effect, as it did not cause the board thus cooled to crack or become more brittle than one which had been cooled slowly.

[1] United States Mineral Resources, 1904, pages 1,130-1,136.

'The various asbestos boards on the market are similar in their construction and composition to those manufactured by the Keasbey and Mattison Company, at Ambler, Pa. These are stated to be composed of 25 per cent asbestos and 75 per cent Portland cement, which are thoroughly mixed together and submitted in sheets to a pressure of about 83 tons per square foot. The magnesia board or sheathing is prepared by permeating the asbestos mill-board with a solution of silicate of soda and bicarbonate of magnesia, the water being removed by subjecting the mill-board to pressure.

'Some interesting tests were made upon samples of the asbestos and magnesia sheathing of the Keasbey and Mattison Company at the Underwriters' Laboratory of Chicago, under the direction of the National Board of Fire Underwriters. The samples submitted for test were 24″ × 36″ in size the two asbestos samples being respectively $\frac{5}{16}$″ and $\frac{15}{32}$″ thick, and the magnesia samples being respectively $\frac{1}{4}$″ and $\frac{9}{16}$″ thick. The samples were mounted upon backings of $\frac{7}{8}$″ undressed white pine and matched, the boards being separated about $\frac{1}{8}$″ at the joints in order that the observations might be made of the heat-conducting properties of the sheathing. In making the tests a brick furnace was used whose interior dimensions were 32″ in height, 32″ in width, and 18″ in depth, and walls 6″ thick. The roof of the furnace was of corrugated iron covered with sand and asbestos board. In the centre of the front wall or side of the furnace there was a square opening 12″ × 12″, which was covered by $\frac{1}{4}$″ iron plate 24″ × 24″, built vertically into the wall and lapping 6″ on all sides of the opening. The heat was obtained by means of a $2\frac{1}{2}$″ Bunsen burner supplied with natural gas at $2\frac{1}{2}$″ pressure, the burner being set horizontally in the rear wall so that its flame fed directly upon the plate. In operating the furnace, the fire was started and maintained for twenty-five minutes before beginning the actual tests. The samples were then placed one at a time in an upright position before the heated plate, the surface being 6″ from the plate. The results obtained by subjecting the $\frac{5}{16}$″ asbestos sheathing or board were as follows:—

FIRE TESTS OF $\frac{5}{16}$″ ASBESTOS SHEATHING, CHICAGO, 1904.

Time of Exposure.	Results.	Time of Exposure.	Results.
Minutes.		Minutes.	
0	Sample placed in position.	24	Charring of wood increases, the charred portions at joints showing red colour in spots; no flame.
2	Very slight buckling of sheathing.	28	Buckling of sheathing slightly increased.
$3\frac{1}{4}$	Escape of vapour.	40	Sheathing shows very slight red colour from rear side away from furnace.
4	Sharp cracking sounds, but no appearance of cracks in surface.	$44\frac{1}{2}$	Backing ignites.
10	Distillation of gas from wood backing.	45	Sample removed, and 3 gallons of cold water dashed immediately upon surface of same.
12	Charring of wood noticed at joints between boards of backing.		
18	Slow charring of wood continues.		

'This sheet of asbestos sheathing was found to be considerably cracked by the application of the water, but did not appear to be disintegrated by the heat, and the surface remained hard and smooth. There was no scaling from the surface detected, the cracks extending through the sheet and the warping were very slight. The pine backing was charred to a depth of one-half inch back of the hottest area.

Carded chrysotile-asbestos, resembling silk fibre.

'The asbestos sheathing $\frac{15}{32}''$ in thickness was subjected to a similar test, with the following results:—

FIRE TESTS OF $\frac{15}{32}''$ ASBESTOS SHEATHING, CHICAGO, 1904.

Time of Exposure.	Results.	Time of Exposure.	Results.
Minutes.		Minutes.	
0	Sample placed in position.	19	Charring continues with considerable smoke; charred wood begins to show red colour.
3	Slight buckling of sheathing.	45	Sample removed, no flame having occurred, and 3 gallons of cold water immediately dashed upon the surface of the same.
4	Escape of vapour.		
10	Distillation of gas from wood backing.		
16	Charring of wood backing begins.		

'The surface of this sheathing appeared to be slightly disintegrated at the hottest portion, but the sheet was not cracked by application of water, nor did it warp after cooling. The wood was charred to a depth of about $\frac{3}{8}''$ back of the exposed area.

'From these experiments it would appear that, although these asbestos sheathings or boards are incombustible, they have fairly good heat-conducting properties when their surfaces are subjected to intense heat. In the experiments described this is due probably, to some extent at least, to the high percentage of cement that was used in their manufacture.

'The two sizes of magnesia sheathing or board, $\frac{1}{4}''$ and $\frac{9}{16}''$ in thickness, were subjected to similar tests with the following results:—

FIRE TEST OF MAGNESIA SHEATHING $\frac{1}{4}''$ THICK, CHICAGO, 1904.

Time of Exposure.	Results.	Time of Exposure.	Results.
Minutes.		Minutes.	
0	Sample placed in position.	10	Backing ignites.
2	Slight warping of sheathing.	$10\frac{1}{2}$	Sample removed, 3 gallons of cold water being immediately thrown on surface of same.
5	Slight upward bulging at centre.		
6	Distillation of gas from wood back.		
9	Wood considerably charred.		

FIRE TEST OF MAGNESIA SHEATHING $\frac{9}{16}''$ THICK, CHICAGO, 1904.

Time of Exposure.	Results.	Time of Exposure.	Results.
Minutes.		Minutes.	
0	Sample placed in position.	22	Charring of wood continues.
3	Slight warping of sheathing.	25	Wood back ignites.
$3\frac{3}{4}$	Sheathing begins to separate into two thicknesses, parting first at the upper edge.	$25\frac{1}{2}$	Samples removed, 3 gallons of cold water being thrown immediately on the surface of same
6	Escape of vapour.		
11	Distillation of gas from wood backing.		

'The surface of these two samples was softened and somewhat disintegrated, being readily cut with a knife where exposed, although retaining its original finish and appearance, with the exception of a darkening in colour. There was no scaling, but the cold water caused cracks to extend through the sheathing. The thicker sample showed more permanent warping after cooling than the others. The wood backing of the thinner magnesia sheathing was charred to a depth of about ¼″ back of the exposed area. The extent of charring in the thicker sample was not determined. These experiments show conclusively that both these materials are superior to wood for the purposes for which they are manufactured, and that the asbestos lumber is considerably superior to the magnesia.

'Such asbestos lumber, when employed in the construction of street railway and standard railway cars for covering the end framing, should prevent the cars from taking fire by any derangement of the electrical apparatus. Enclosing the circuit breakers in boxes of this material would prevent conflagration if there should be any defective arching. There are a number of railway companies that are beginning to use this material, and the Street Railway Journal of August 20, 1904, states that the New York City Railway Company is using this asbestos for the lower parts of new double-truck cars which they have recently built.[1] The Interborough Rapid Transit Company is also using asbestos board for various insulating purposes in the New York City subway. The General Electric Company is using the asbestos building lumber for finger shields, arc deflectors, barriers, panels, hot-air ovens, linings, and also under floors. The Brooklyn Rapid Transit Company is using asbestos building lumber in their new cars, the specifications providing that the underflooring of these cars shall be covered with asbestos building lumber of not less than ¼″ in thickness. The Montreal Street Railway Company have also recently specifier that this material shall be used in new cars that are being built for them by the J. G. Brill Company, and the Niles Manufacturing Company.

'Another type of asbestos building material that is beginning to be used quite extensively is asbestos board or sheathing for roofing and a similar material for side walls.

'The materials of this sort examined were manufactured by the H. W. Johns Manville Company, and are composed of strong burlap or canvas foundation, having asbestos felt on the under side, and on the upper side either one sheet of saturated asbestos felt finished with a sheet of plain asbestos or two sheets of saturated asbestos felt. The whole is cemented together with a specially prepared acid-proof and waterproof compound, and is compressed into a compact, flexible roofing sheet. This kind of roofing gives fireproof qualities to the roof, and there are now many manufacturing plants that use this material quite extensively as a covering for their buildings, not only on the roof but on the side walls also—as, for example, the Standard Plate Glass Company, Butler, Pa.; the Allis-Chalmers, Chicago plant; the New England Cotton Yarn Company, New Bedford, Mass.; the Northwestern Malleable Iron Company, Milwaukee, Wis.; the Boyer Machine Company, Detroit, Mich., etc.

'An asbestos shingle has recently been patented (August 30, 1904) by Messrs. Keasbey and Mattison, which is composed of asbestos fibre and hydraulic cement. These shingles were examined by the writer, and are much stronger than slate, and lighter in weight. They are made in square, 4½″ on a side, with two corners of the square truncated. They are manufactured in three colours—grey, slate, and brick or tile red.

[1] Street Railway Journal, August 20, 1904.

'There has been kept in mind in the manufacture of these asbestos building materials the preparation of materials that would not only have the requisite strength and the desired fireproofing qualities, but that would also be attractive in appearance and be easy of manipulation and application.

'It will be seen from what has been said that there has been a considerable advance made during the last few years in the utilization of asbestos in the manufacture of building materials, and that it is now possible to substitute these asbestos building materials for wood and building paper in almost any kind of building that may be constructed, as the asbestos board is now manufactured in such shape that it can be stained, polished, and finished to nearly as high a degree as wood. It can also be made very tough, so that it can be used to advantage as flooring. Although there will not be perhaps a general use of these asbestos materials for decorative purposes in private houses, they should be used to a considerable extent in public buildings and hotels, and especially in theatres and other buildings that are used for large gatherings. With the materials that are now manufactured from asbestos it would be possible in the construction of a theatre to eliminate all woodwork and even cloth, as asbestos carpets could be used on the floors, and asbestos cloth could be used for upholstering chairs, and for curtains and shades to windows. These materials are considerably more expensive than the corresponding wood or cloth, but they will wear as long, if not longer, and in addition they are fireproof, which would add to the safety of those patronizing the theatres, as well as reduce the cost of insurance.

'The use of asbestos materials in building has been considered chiefly from the standpoint of fireproofing; yet there is another and perhaps as important a reason for their employment, and that is for preserving an even temperature in the building erected. This applies both to those regions where there is extremely hot weather of long duration, as in the Southern and Southwestern States, and also regions of long continued cold weather. Houses so built as to be surrounded by asbestos should be cooler in summer and warmer in winter than other houses. Where such roofing and side-wall material as has been described can be utilized it will serve for three purposes: as a covering for the building, as a fireproof material, and to keep out the heat in summer, and to keep in the heat of the heating apparatus in winter. When it is impracticable, as in framed dwelling houses, to use the materials described, there are various asbestos sheathing papers, or better, asbestos building papers up to ⅛″ in thickness, that can be used between the sheathing boards and the clapboards or weatherboards on the side-walls and just underneath the shingles of the roof. An experiment with these materials is now being made on a house in North Carolina which is in process of construction. Asbestos material is being used between the flooring of both the first and the second floors; asbestos mill-board ¼″ thick or two sheets of ⅛″ asbestos board are used to wrap all joists that come in contact with the chimneys, and all wood is separated from the chimneys by means of this same material. All electric light wires and connexions are separated from the woodwork by asbestos board or paper. The furnace, the furnace pipe, and the hot-air flues are also all separated from woodwork by asbestos board or paper. Thus it is seen that asbestos can be used in considerable quantity and to good advantage in a private residence, and while the first outlay adds somewhat to the cost of the house, at the same time it reduces

the chances of fire, makes the house more comfortable both in summer and in winter, and reduces the cost of insurance.'

WALL PLASTER AND ASBESTIC.

These new specialties came into prominence when the Danville Asbestos Company of Quebec commenced operation, in the year 1896. They consist of asbestos and serpentine, and are consequently incombustible and fireproof. Their value, therefore, as a protection against fire when used for plastering walls and ceilings, is undeniable.

Asbestic is now used in fireproof buildings in cities like New York, London, Montreal, and Chicago, and forms one of the principal fireproofing materials. It is generally made in two qualities, in rough 'asbestic' and what is called the 'finish.' The former may be applied to the walls of a new building, upon brick, metal laths, plain boards, or expanded metal; and when dry will form a coating of the nature of asbestos felt board, which is now so much used in the United States. This coating is then covered again with the 'finish,' which is a carefully prepared pure asbestos fibre of remarkable fineness.

FIG. 74.—Residence covered with asbestos stucco. (Asbestic.)

Another application of the fine asbestic plaster is in the construction of the so-called Salamander decorations as made by the United Asbestos Company, London. The fine fibre for this use is mixed with some pulverized ingredients and special liquids; then moulded, and pressed into forms. The product so manufactured is light in weight; is more easily applied than other embossed decorations; and on account of its fibrous nature, grips walls and ceilings with great tenacity and power.

Uralite[1] is the name given to a new fireproof material composed of asbestos fibre, chalk, sodium bicarbonate, and silicate—invented by a Russian artillery officer and chemist, named Imschenetzky. It is a non-conductor of heat and

[1] Mineral Industry, 1900, page 50.

electricity, and is practically waterproof. The manufacture of uralite consists in teasing the asbestos fibre and freeing it from sand and other foreign substances; after which a little whiting is added, and the mixture is run through a disintegrator; then separated by air blast, and sifted. A quantity of whiting equal in weight to that of the asbestos is made into a paste, then the asbestos is added, and thoroughly mixed. The mixture is delivered to a revolving blanket and passed through a series of rolls, where it is partly dried and compacted. Fourteen or fifteen thicknesses are passed to a revolving drum, and a solution of sodium silicate and sodium carbonate added to serve as an adhesive. The layers are subjected to a pressure which is finally increased to 200 pounds per square inch, and left for one and a half hours; after which they are dried for one day. When dry they are gradually heated in a gas-fired oven, cooled. steeped in a solution of sodium silicate, washed, dried, and again heated These operations are repeated until the proper hardness is attained.

'Manderite' is a dense, firm, highly burnished fireproof asbestos sheet, which is adaptable to decoration of any form, and is used for wainscotting, ceilings, and side walls. It is also especially adapted for interior fireproofing of cars and steamships.

'Ceilinite' is a flexible asbestos felt product, reinforced with asbestos cloth, and intended primarily for the fireproofing of the inner roof of electrical passenger coaches. When in use, the fire resisting sheet is held in place by a thin sheet of another metallic substance, put on as a facing board.

Corrugated fireproof paper or 'Asbestocel' consists of corrugated asbestos paper, backed by a plain or flat layer of the same material. Being flexible, it can be readily handled and cut into any desired lengths: which makes it specially suitable for wrapping heated pipes, lining floors, and other surfaces requiring thin, flexible, insulation.

'Asbestocel Sheets' are built up from successive layers of asbestocel paper, the plies being laid on each other; so that the corrugations of the one run at right angles to those in the preceding ply. By this method the sheets contain a large number of air cells, which greatly improves their insulating power. They are easily sawed to fit any sized surface, and conform readily to the curve of boilers, furnaces, etc.

A. Truchenetsky[1] has patented a method of manufacturing fireproof decorations by treating asbestos with a solution of alkaline silicate of soda; the colloidial silicate uniting the threads of asbestos. A dilute solution of an alkaline silicate is used and the mass is then immersed in a saturated solution of alkaline bicarbonate. This deposits the silica between the asbestos particles.

A new composition, the principal ingredients of which are shellac and asbestos, has been invented in Germany, and application for patent rights has been made. The advantages claimed for it are cheapness of raw material, hardness, and lightness of weight. It is fireproof, and can be handled as readily as wood.

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1 Mineral Industry, 1899, page 46.

ASBESTOS PAINTS.

The manufacture of fireproof paint has, in recent years, assumed considerable importance. Nearly all the manufacturers of asbestos goods make asbestos paints in various colours.

These paints are suitable for rough woodwork, such as joints, rafters, beams, stairs, warehouses, and wooden structures of all kinds. Numerous public experiments have been conducted from time to time proving the remarkable fire resisting qualities of asbestos paint.

ASBESTOS BOARD.[1]

For the purpose of preparing accumulator casings, insulating boards from asbestos sheet, cardboard, and cloth, the material is impregnated with potassium, or sodium water glass of specific gravity=1·1. By this impregnation it becomes so soft that it may be 'lapped' without breaking. The cardboard, etc., is then so shaped by the use of the 'lapping machine' that the sides for the accumulator casing produced, are composed of two layers, and the bottom boards of three layers. The casing, after drying in a heating chamber at 125° C, is then submitted to a second process of impregnation, with resin, wax, or paraffin, at a temperature of 200° C during from six to eight hours. It is said that after this process, the material becomes so solid and hard that it may be 'treated by planing, grinding, or sawing,' like 'horn, ivory, or vulcanite' It is, moreover, heat resisting, as well as water and acid-proof.

TESTING ASBESTOS BOARD.

According to *L'Industrie,* asbestos board of good quality weighs about 1 kilogram per square metre for each millimetre in thickness. It ought to resist a dynamometric tension of 400 to 500 grains per square millimetre of section. In order to judge the purity of asbestos board it should be reduced to a paste by means of warm water, and thoroughly macerated. The paste is then transferred to a sieve of No. 30 to 32 wire cloth, and washed several times, to remove foreign matter. The residue is dried without calcination, and weighed. The loss in weight from the amount originally taken should not exceed 20 to 25 per cent.

Testing asbestos board by calcination is less conclusive than the washing test; since it does not show whether it contains such foreign matter as china-clay.

ASBESTOLITH TILING FOR FLOORS.

A new product called asbestolith—a German invention—is now being made by the Sall Mountain Asbestos Company at Saulter, White county, Ga., U.S.A. It consists principally of short fibred asbestos, and is used chiefly in the preparation of cement and tiling for floors; for which it is claimed to have superior advantages: among them, impermeability

[1] Chemical Industry, 1899, page 500.

to water, and elasticity as high as that of wood; hardness equal to that of cement, greater durability than asphalt, lightness in weight; and is a non-conductor of sound. It is also claimed for it, that it will not crack, warp, or bend, and shows greater resistance to abrasion than stone, brick, or marble.

ASBESTOS PROTECTED METAL.

For a long time there has been a constant demand for a light building material capable of resisting rust, and rendering permanent service in the construction of factory buildings, warehouses, grain elevators, automobile-garages, etc. Such an article is now manufactured by the Asbestos Protected Metal Company, of Canton, Mass. This specialty, known as asbestos protected metal, is composed of a body or core of annealed sheet steel, which is immersed at a very high temperature in a bath of cement compound, prepared in accordance expermentation on the part of a roofing expert, and possesses unique preserva-

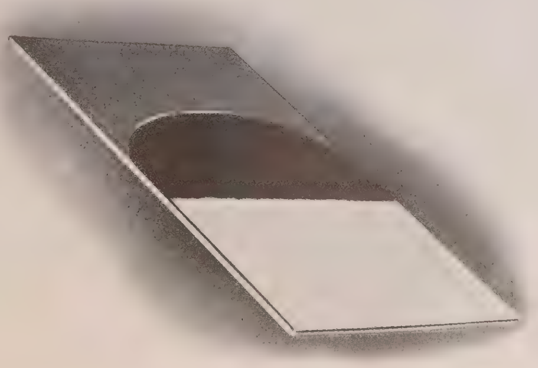


FIG. 75.—Construction of asbestos protected metal. Grey surface represents the steel core. The black surface represents a coating of special asphaltum compound, applied to the steel core under great heat and pressure. The white surface shows pure asbestos felt firmly embedded in the asphaltum compound. (NOTE.—The coating of asphaltum compound equals in thickness at least five coats of heavy protective paint. The finished product is of the same construction on both sides of the sheet.)

experimentation on the part of a roofing expert, and possesses unique preservative qualities. The intense heat of the sheet during immersion opens the pores of the metal, and allows the compound to penetrate therein. After this immersion takes place the sheet of steel is passed through a pair of hot dripping rolls, which remove all the surplus compound, and render the coating even and clear. Pure asbestos felt is then applied to both sides of the sheet under great pressure, and each sheet is afterwards cooled slowly; gradually contracting and hardening until its different component parts—steel, cement, and two layers of asbestos felt—are combined into a practically solid mass. The result is a material which will resist fire, water, gas, and sulphur fumes, and the corrosive,

[1] Engineering and Mining Journal, 1899, page 22.

destructive ravages of the elements for an indefinite period. It possesses strength, rigidity, and lightness of sheet iron, combined with the portability and ease of application of the most satisfactory of the ready-made roofings.

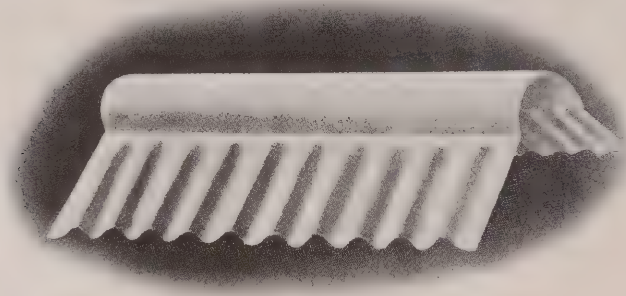


FIG. 76.—Asbestos protected metal corrugated ridge capping.

The steel core—which is the strongest feature of asbestos protected metal —is absolutely protected, and is immune from the attack of any natural agent: whether it be used on the exterior or interior of a structure. The most severe climatic conditions will have no effect upon it as the coating is perfect. This

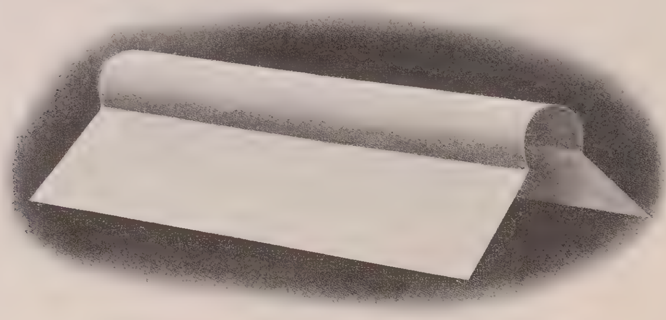


FIG. 77.—Asbestos protected metal flat ridge capping.

cement coating is itself protected by pure asbestos felt, with which it is covered —on both sides of the sheet. The asbestos is not saturated, but retains its clear, white surface on its exterior sides, and is absolutely fireproof. (Figs. 76 and 77.)

Asbestos in Electrical Machinery.

A new method of insulating metallic surfaces has been patented by John A. Heaney, Philadelphia, U.S.A.[1] This method consists in applying to the

[1] Engineering and Mining Journal, 1902, 11, page 55.

metallic surface: (1) a paste or cement; (2) in embedding asbestos in fibrous or flaky form in the cement; and (3) covering the asbestos with a solution of chemical or metallic salts, combined with a gluey or albuminous substance containing lime.

Asbestos is used in the form of mill-boards in the construction of dynamos. It is used in tubes and elbows for turning corners. Battery plates are sometimes wrapped in asbestos paper; and asbestos gloves lined with rubber serve to handle electric wires with comparative safety.

A composition for the insulation of metallic conductors, consists of a layer of asbestos which covers the surface to be insulated; and a coating of oil combined by boiling with litharge and red lead, until the free acids of the oil have been expelled.

Miscellaneous Uses, and Manufacturing Processes.

Uses for Clean Fibre.—Asbestos fibre is used to some extent—especially in England and the United States—in connexion with gas fires. The gas is made to rise through asbestos fibre and is then lighted. The asbestos fibre glows brightly while the gas is burning with a blue flame; which serves not only to distribute the heat; but exhibits the pleasant appearance of an open-hearth, wood or coal fire.

Asbestos in the shape of 'carded fibre' is in large demand for many industrial and domestic purposes. The gas logs for open fireplaces are faced with asbestos, Christmas trees, and 'Santa Claus' are both covered with this mineral cotton in those parishes where life and property are held sacred; while the hundreds of thousands of lamps used upon automobiles, yachts, etc., consume acetylene gas fed from absorbtive reservoirs of asbestos fibre.

'Asbestos socks' are the newest invention. They are called in the trade 'Basco Socks' or 'Dr. Bright's Asbestos Socks,' and are manufactured by Messrs. Steel, Resdaile & Company, 4 Domingo Street, London, E.C. These socks are made of specially prepared asbestos cloth with a cork base impregnated with boric acid. The socks are practically indestructible and at the same time soft and pliable in wear, and with an elasticity that is often absent in other makes. A pair can be had at 7d., a low price considering the quality of the material supplied.

Cold Storage.—For the preservation ot meat, and all kinds of provisions, specially constructed ships, containing the necessary refrigerator apparatus and chambers, are in universal use. In the large American cities special cold storage buildings have been erected. Nearly all of these have double walls surrounding the cold chambers, with some kind of non-conducting material. For this purpose asbestos has been found specially suitable. In recent cold storage construction this article has been used very extensively.

Asbestos as a Filter Medium.—Very fine fibre, which has been subjected to a process of cleaning, is used to a large extent as a filtering medium. It resists the action of alkalies and acids, and after filtration it can be easily

cleaned by hot water or steam. In case of a hard tenacious residue, the filter can be thrown into the fire, and after the residual matter has been consumed, the fibre will be found unimpaired, and ready for use again.

There are many different kinds of asbestos filters in use: the 'Maignen's Filter rapid'—which consists of a hollow perforated cone of eathenware, over which a specially woven asbestos cloth is stretched; the 'Nibestos Filter,' which consists of an upper and lower earthenware vessel divided by a strainer of like material, upon which is fixed a sheet of specially prepared asbestos cloth, and above this again another sheet of much finer texture. This filter is said to render excellent service in the purification of water.

In the Laboratory.—In the laboratory, asbestos in its various forms is a very useful substance, and can be employed very readily in many ways on the lecture table. Asbestos twine is used in binding together parts of apparatus exposed to fire and strong acids. To prevent spreading of a crack in the neck of a retort or flask, it is only necessary to bind it with asbestos yarn or twine soaked in a solution of sodium silicate and then treated with a solution of calcium chloride, and a perfectly insoluble cement is the result. Asbestos wool mixed with a solution of silicate of sodium makes a fireproof cement of great strength, and also serves to mend cracks in stoneware. It can be made insoluble by subsequent treatment with calcium chloride—silicate of calcium being formed. Asbestos paper and card, having all degrees of thickness, are employed as substitutes for wire gauze and the sand bath in small operations involving the heating of glass vessels. Asbestos paper and silicate of sodium are very useful for mending cracks in glass apparatus.

Asbestos Leather.[1]—A new use for asbestos is the manufacture of asbestos leather: which is made by dividing asbestos into very fine fibres, immersing and thoroughly coating them with a solution of rubber, and afterwards evapcrating the solvent: the fibres then cohere perfectly. A mass may be pressed or rolled into any desired form and the product is said to resemble leather very closely in its structure and general characteristics.

In the Kitchen.—A number of household articles are now manufactured of asbestos, amongst these may be mentioned:—

Asbestos Table Mats.

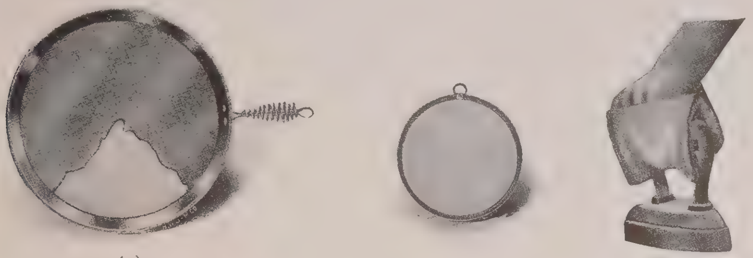
Asbestos Baking Sheets.—Used for regulating the browning of bread, cakes, roasts, etc. When the baking article is browned sufficiently on top an asbestos sheet is loosely placed over it, after which it may be left in the oven until done, without danger of burning.

If the oven bakes too rapidly on the bottom, an asbestos stove mat placed under the pan will remedy it.

Asbestos Stove Mats.—These mats are about the handiest utensils in the kitchen. They prevent scorching or burning either the food or the utensils and make stirring unnecessary.

[1] Mineral Industry, 1898, page 63.

Asbestos Lined Cooking Utensils.—Griddles, pie plates, and omelette pans. The materials used are the best cold rolled steel and heavy sheets of pure asbestos. These various utensils are made with an asbestos lining between the sheets of steel, which prevents burning or scorching of the contents.



(a) (b) (c)

FIG. 78.

(a) Omelette pan, consisting of two steel plates with sheet of asbestos between.
(b) Stove mat.
(c) Iron holder.

Asbestos Toaster is a heavy asbestos mat, backed with sheet steel, covered with a fine wire mesh, and fitted with cold handle. It is specially designed for toasting; since it diffuses the heat over the entire surface, thereby rendering the article equally brown all over.

Asbestos Stove Polisher.—This is a wooden brush back, with a face of asbestos cloth instead of bristle. The cloth is backed by a soft asbestos pad and may be used on the hottest stove without harm or unpleasant odour.

Asbestos Flat Iron Holder.—For the laundry or kitchen. A soft heat-resisting pad, faced with asbestos cloth. It cannot burn; and is used in the handling of hot irons, dishes, etc.

Asbestos Iron Holder.—Similar to the asbestos flat iron holder; with the exception of an extra piece of asbestos cloth, so fastened to the back that a

FIG. 79.—Asbestos brake.

pocket is made for the hand, which makes possible a more secure hold on the iron, and thus prevents the possibility of scorching the hands. This holder is thickly padded, resists heat, and is inodorous.

Brake Lining.—A non-burn, brake band lining is now manufactured by the Johns Manville Company, of New York. This article has been applied effectively to brakes on automobiles, and is made of pure long fibre asbestos, with wire interwoven.

TREATMENT OF ASBESTOS FOR RENDERING IT WATERPROOF.[1]

Asbestos articles, which are naturally hygroscopic, are rendered waterproof by the following process: the articles for use at ordinary temperature are coated with chrome glue, alum glue, or chrome-alum glue, or they are coated first with a solution of resin soap, and afterwards treated with a solution of calcium chloride, which forms with the soap an insoluble compound on the surface and in the pores of the article. When the articles are to be subjected to high temperatures, they are either coated with water-glass, or a glass or porcelain enamel is burnt on to their surface.

IMPROVED TREATMENT OF ASBESTOS DIAPHRAGMS TO ENABLE THEM TO RESIST DISINTEGRATION.[2]

To prevent the disintegration of sheet asbestos made without the addition of any binding material, when under the action of liquids, it is heated to a temperature below that to which vitrification occurs by immersion in a bath of molten aluminium at 600° to 700° C. Sheet asbestos treated in this manner forms an excellent material for diaphragms in the electrolytic production of alkali.

APPLICATION OF ASBESTOS TO THE MANUFACTURE OF FIRE RESISTING AND REFRACTORY MATERIALS USED IN BUILDING CONSTRUCTION, ETC.[3]

Asbestos reduced to a fibrous powder, mixed with powdered clay and refractory earths, made into a paste with water, moulded into the required shape, then dried and burnt, furnishes a valuable refractory material. This material may be used for bricks and paving, as well as for furnaces, retorts, crucibles, etc. In addition to its refractoriness, it is claimed to be light and very hard, and is useful for accoustic insulation.

PROCESS OF USING FIBROUS ASBESTOS IN THE FORM OF A LIQUID OR PLASTIC MASS.[4]

Powdered fibrous asbestos is added to sulphate of alumina, and a solution of agar-agar, to form a plastic or liquid mass, which will set hard and with the

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[1] Chemical Industry, 1902, page 1,143.
[2] Ibid, 1902, page 1,212.
[3] Ibid, 1903, page 555.
[4] Ibid, 1903, page 699.

addition of suitable filling material, can be used as a covering or insulating material; as an impregnating liquid; or for the production of articles made entirely of this material.

PROCESS FOR MAKING MOIST ROLLS OF ASBESTOS, SUITABLE FOR SPINNING.[1]

Short-fibred asbestos, or similar material, is converted into a pulp, and run as a broad endless web on the paper machine. After draining and pressing, the web is reeled in the usual manner, being slit longitudinally during reeling into strips of a suitable width, which form an apparently coherent roll. If preferred, the web may be slit after reeling by cutting the whole roll transversely into a number of discs. Another method of slitting consists in directing the web of pulp in the moist state under a series of jets of air, steam, or liquid; which have the effect of dividing it into a series of strips, capable of being reeled as a coherent web. The strips, in whichever way prepared, are subsequently unreeled, and subjected to the action of suitable twisting machinery, to form threads.

BEHAVIOUR OF ASBESTOS IN NON-LUMINOUS FLAMES.

Mr. S. Sauberman (Chem. Zeitung, 1902), calls attention to the behaviour of asbestos yarn when heated in non-luminous flames. This yarn is prepared by arranging pure serpentine asbestos—as free as possible from iron—in the roving machine, in such a way that, after carding, it is spread out between two layers of cotton. By this means it becomes mixed with a certain definite percentage of cotton, and can be spun into very thin threads in which the asbestos fibres lie approximately parallel to one another. When a yarn composed of such fibres is placed in a Bunsen flame, the cotton is first burnt away, after which the asbestos fibres give up water and become brittle. Then they begin to soften, and finally fuse together to form apparently homogeneous rods, which become welded in the flame and give out a constant bright white light. This takes place even in the less hot parts of the flame. When cold, the threads are white, hard, brittle, and porous, and in general resemble unglazed porcelain. The fracture shows no signs of the fibrous formation of the asbestos. Microscopic examination proves that the fusion is not confined to the surface, and it is only at those parts where knots have been left in the fibre that there occur little nests of externally fused matter containing asbestos fibres. The composition of serpentine asbestos is changed by this treatment from $H_4Mg_3Si_2O_9$ to $Mg_3Si_2O_7$; while that of hornblende asbestos remains as before: namely, $Mg_3CaSi_4O_{12}$. The light emitted by this mineral when heated can be greatly increased by soaking it in solutions of salts of the alkaline earths; or better, in nitrates of the metals of the beryllium group. A thread prepared in this way, and weighing 0·02 of a gramme, when heated in the non-luminous flame of acetylene burning at the rate of 10 litres per hour, emitted a light from 12·5 to 13·5 normal candles. The complex silicate forms a very intimate mixture with a basic oxide, traces of which are retained, even on treatment with various solvents.

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[1] Chemical Industry, 1903, page 757.

MANUFACTURE OF FIBROUS FIREPROOF SHEETS.[1]

The fibro-cement, asbestos, or other pulp is supplied to a service-box, in which it is kept from settling, and which discharges it by means of a channel and apron, in regulated width and depth, onto a wire sheet travelling over a wire cloth drum or drums serving to drain the water from the pulp, which is squeezed between the wire drum and a felt-covered Couch roll or rolls. The film formed is picked up by the felt, and passed on to a collecting drum; it is then wound around this drum and compressed together with the preceding layers between the drum and a roll supporting the drum so as to consolidate the successive film layers into a film sheet until the desired thickness of sheet is attained; after which the sheet produced is severed and uncurled from the drum. Adhesion between the successive layers wound on the drum may be effected by placing cementitious matter between the layers. Wire cloth may also be fed on to the drum together with the fibrous layers, and incorporated with them.

BINDING OF ASBESTOS FIBRE.[2]

Sheets or articles are prepared by making a mixture of powdered aluminium silicate, sodium silicate, and water, which is used to impregnate, and fill the spaces between asbestos fibres; and the articles formed are dried, and finally baked at a temperature of about 800° F, or less.

PREPARATION OF ASBESTOS ARTICLES FROM FINELY DIVIDED ASBESTOS, WITHOUT THE USE OF BINDING AGENTS.[3]

T. Bernfeld, German Patent 160,987, April 19, 1904. Addition to German Patent 148,936, June 12, 1901.

In order to render the asbestos articles resistant to acids, they are impregnated with a warm or hot solution of water-glass (alkali-silicate) from which silicic acid is separated subsequently, by known means.

The Use of Asbestos in Mines.

The application of asbestos in mines is confined to the insulation of steam connexions. The problem which confronts the mining engineer is how to secure good results with a steam boiler at the mouth of the pit connected to a pump several hundred feet underground; or a fan several hundred yards away from the boiler; necessitating the use of long lines of steam pipe which must be covered with a non-conducting material to prevent the radiation of heat.

This pipe often runs close to the tracks, in slopes and along haulage roads; or is hung perpendicularly in shafts, where it meets with the roughest usage and is often subject to the constant drip of water—sometimes strongly charged with sulphides.

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[1] Journal Society of Chemical Industry, 1905, Vol. 1, page 136.
[2] Ibid, 1905, Vol. 2, page 926.
[3] Ibid, 1905, Vol. 2, page 1,233.

Of what form and of what materials to make an insulator that will be of service under such trying conditions is the question that must be solved. That the pipe must be covered is scarcely a matter of debate. Assuming the pipe to be 4″ internal diameter, and the run say 1,000 feet, the exposed iron surface will be 1,250 feet: *i.e.*, the equivalent of a flat surface 125 feet long, by 10 feet wide.

Assuming further, a steam pressure of 70 pounds, we have a body at the temperature of 316° F, 1,250 square feet in extent, constantly radiating into an atmosphere about 250° cooler than itself, with results which anyone familiar with condensation of vapours can easily predict. Theoretically, it would take over 8 tons of coal per annum to remedy the waste in each 100 lineal feet of pipe, or, at $3 per ton, $24 per 100 feet, making a total waste on the line of pipe in question of $240 per annum; and aside from the expense involved, the water of condensation clogging the cylinder and valves of the pump would stop the motion of its pistons and injure the machinery.

With the pipes properly insulated by the application of good non-conducting covering, this loss can be practically prevented, and perfectly dry steam delivered at great distances from the boiler.

The loss from radiation under such favourable circumstances is infinitesimal, and when compared with the loss of waste through friction and other causes is not worthy of note. It is difficult to obtain reliable data owing to the difficulty of making accurate observations on apparatus of such great length. In a recent test, however, of a system of piping carrying hot water under pressure at 400° F the total loss in a travel of 10,000 feet, chargeable to radiation, was placed at 3 per cent. These tests were made by competent engineers, and with every means known to science. All the pipes in question were insulated with asbestos 1½″ thick.

Having considered the conditions and possibilities of steam transmission economy in mines, we now revert to the main question: what material, if any, will answer the purpose.

A suitable material must fill the following requirements:—

(1) It must be a non-conductor of heat.

(2) It must be unaffected by heat.

(3) It must be unaffected by water.

(4) It must be capable of standing rough usage.

An extensive list has been offered by enterprising vendors, of articles and devices for fireproofing, water-proofing, etc.; which have one after another been discarded in consequence of some fatal defect.

It may be interesting to critically consider a few of these, to see in what way they fall short of the standard requirements: durability under heat, water, and rough usage.

In the case of hair felt—the oldest form of pipe covering in use, and one of the best non-conductors of heat known, on account of the great number of air cells it contains—experience has demonstrated that it is short lived under heat, and that it disintegrates rapidly when wet. The various fireproof linings used under hair felt do, it is true, prolong its life; but do not give it real dura-

bility, hence, for mine work it can not be recommended. An extended list of paper pulp and wool felt materials—usually made up in sectional or cylindrical form—appears in the market as fireproof material. Some of these have a thin sheet of asbestos as a lining, placed there more for appearance than use; but close examination shows that the asbestos is too thin to afford much protection.

The best type of this covering is made of alternate layers of wool felt and asbestos sheeting, laid up in cylindrical form so as to leave air spaces. But this covering, while efficient and durable under ordinary circumstances, will not stand the exposure of a mine shaft; the wool felt chars, and leaves the asbestos.

The disintegrating effect of heat and moisture on organic substances is well known. Hence these, and similar coverings containing a large percentage of hair, wool, and other organic matter are rapidly destroyed in mines; and the general proposition is laid down, that no covering should be adopted for use in mines that contains organic matter in its composition.

The various forms of non-conducting cements, while more durable under heat, are too easily injured by rough usage to last long in a mine. These non-conducting cements are of two kinds: (1) containing heavy clays or earths with animal or vegetable fibres as binders, and (2) those made from asbestos and infusorial or fossil earths. The former are only nominal pipe coverings, since they do not retain the heat, and consequently have no real value; the latter have merit, but are not of any service in mines.

In connexion with these cements or plastic coverings we find in use several made by mixing magnesia or plaster with asbestos. The asbestos acts as a binder, and adds to the strength of the plastic compound, which is formed into sections or slabs; but the objection urged against the use of cement in mines applies with equal force to this form of material: it is not durable.

Experience has shown that in the case of the various forms of non-conducting coverings the materials used in their make up, other than asbestos, cannot be recommended for use when exposed to great heat, continued moisture, and rough usage; and that whatever durability they possess is due to the asbestos fibres which they contain.

It is an established fact that the non-conducting property of a material depends not so much on the elements of which it is composed as on the mechanical arrangement of its constituent parts. A material which is made up in solid and compact form, so that its particles are in close contact, will be a poor non-conductor of heat. If, however, this same material be so made up as to form numerous air cells between the particles of its fibres, it will then prove an excellent non-conductor of heat. Only such fibre resisting substances as admit of such cellular structure are useful as non-conductors of heat. Asbestos, for instance, in the compact form of mill-board or sheeting, is only a fair heat-insulator; while in the loose or fibrous form it is one of the best non-conductors of heat known.

In conformity with these well established facts, the non-conducting covering which answers best for all mining purposes is made from fibrous asbestos.

The asbestos is taken in its crude or natural state, and by special processes is cleansed from all foreign substances; and the long silken fibres are selected.

separated, and divided until they may be formed into as loose and fine an aggregate as cotton batting. Asbestos thus treated, is not alone a good non-conductor, but will withstand the intense heat to which it may practically be subjected; and, being free from all organic substances, is unaffected by water.

The material prepared as described above is shaped by special machines into cylindrical form, of sizes to fit pipes of any diameter and of any required thickness.

These cylinders or sections of asbestos are then cut on one side so as to open and slip over the pipe, after which they are neatly jacketted with suitable material and provided with bands and buckles to hold them in place.

For mine work, under favourable conditions, the jacket is a light cotton duck, which is afterwards coated with a waterproof paint to keep the covering as dry as possible. But in very wet places, and under trying conditions a jacket of asbestos and wire cloth is substituted. This is a special material, formed by uniting layers of asbestos through the meshes of wire cloth, after which the material is waterproofed. This forms a jacket of great strength and durability, unaffected by heat, and impervious to moisture.

The jackettings are to give finish to the coverings, and also to prevent any excess of moisture in them; for the filling of the air cells would deteriorate the insulating capability. The covering, however, does not depend on the jacket either for its strength or for its protection, as the asbestos fibres from which it is made have, in themselves, great strength, and will stand very rough handling. If the coverings become wet, they dry out again without any injury.

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APPENDIX

THE TESTING OF HEAT-INSULATING MATERIALS[1].

By Frederic Bacon, M.A., A.M.I.E.E.

Within the last two years several important contributions have been made to our knowledge of the problem of heat insulation. In *Engineering,* of January 1, 1909, is to be found a summary of the very exhaustive investigation of the physical properties of materials commonly employed for heat insulation, carried out by Dr. Nusselt in the *Technische Hochschule* of Munich. The experiments cover a wide range of temperature, and one of the most remarkable results was the establishment of the fact that the heat conductivity of such materials is not constant, but increases with rise of temperature. The principal method adopted in the above-mentioned research was to measure by means of a large number of thermo-electric couples the heat gradient set up in a spherical shell of the insulating material built round a central electric heater.

Again, in *Engineering* of July 9, 1909, Mr. Charles R. Darling gives an account of the results he has obtained with a simple laboratory apparatus designed to test steam-pipe and boiler coverings under conditions imitating actual practice. The arrangements consist of a closed metal vessel containing an electric heater and lagged with the material to be tested. Observations are made of the average internal temperature and the electric energy supplied to the heater.

The original object of the apparatus now to be described was to obtain some exact data for calculating the loss of heat through the walls of cold stores in which only a very thin layer of insulation could be allowed, so that surface effects were important, and to provide a conductivity test for heat-insulating material which could be carried out with sufficient ease and rapidity for commercial purposes. Dr. Nusselt's method of observing the heat gradient in a spherical shell of material surrounding a central source of heat is an ideal method for determining the heat conductivity from a purely scientific standpoint, but is extremely laborious to carry out, and is not well adapted for testing materials supplied in block form. In addition to the long time necessary for preparing the apparatus and the large number of observations that have to be taken and reduced, a considerable amount of material is required, and the calculation of the coefficient of conductivity is a matter of some complexity, owing to the fact that the radial heat gradient in a spherical shell is not a straight line.

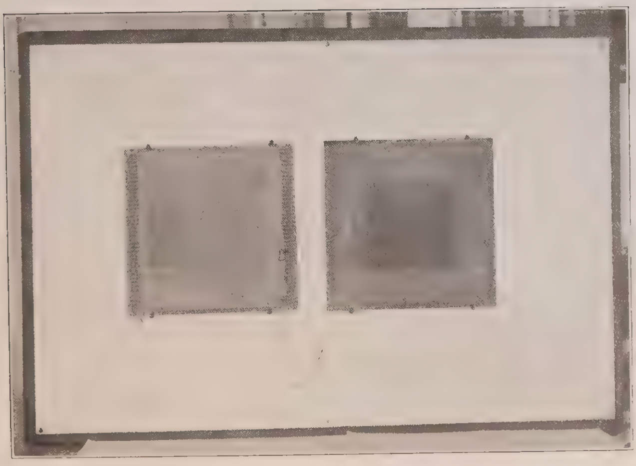
In order to avoid the labour and difficulty of moulding the material to be tested into a shell or covering of complicated shape, recourse was had to the more direct 'wall' method, in which the drop of temperature between the two

[1] Paper read before Section G of the British Association, at Sheffield, September 6, 1910.

PLATE LXV.

General arrangement of apparatus, showing the ammeter, voltmeter, wheatstone bridge, and reflecting galvanometer.

PLATE LXVI.



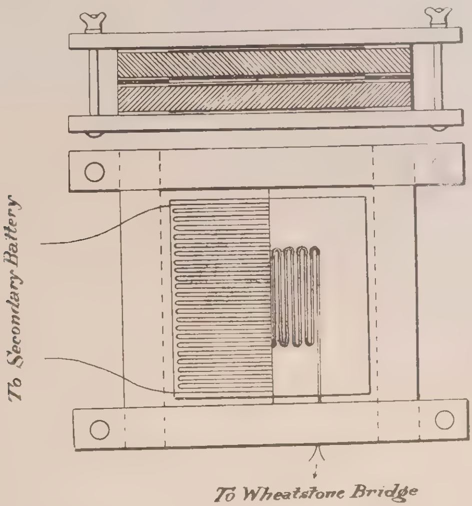
Asbestos woven heating net and coils of fine wire.

To the left: The asbestos woven heating net.

To the right: One of the coils of fine wire wound on the face of a zinc plate, used for measuring temperature.

faces of a thin slab transmitting a known heat flux is determined. The inherent sources of error to which such a simple method is liable are: (1) leakage of the heat flux; (2) incorrect determination of the temperature of the surfaces. It is claimed that both of these errors have been rendered negligible. In fact, the accuracy with which the heat flux and temperature gradient could be determined was greater than could generally be turned to useful account, owing to the want of uniformity existing between two specimens of the same material.

Duplicate specimens of the material to be tested are obtained in the form of slabs measuring 18″ × 18″, and not more than 1½″ thick. A thin, flat heating-net of uniformly-wound resistance wire, interwoven with asbestos (those manufactured by Messrs. Schniewindt of Neuenrade, are excellent for the purpose), measuring 12″ × 12″, is sandwiched in between these slabs, the marginal crack left all round the heating-net being filled up with strips of felt. A photograph of one of these coils is shown to the left, on Plate LXVI. Direct contact between the heating-net and slabs of insulating material is avoided by interposing a thin sheet of asbestos mill-board on each side. To measure the temperature of the faces of the slabs, advantage is taken of the fact that there is no perceptible drop of temperature between a heat-insulator and a good conductor of heat in close contact with it[1]. Sheets of zinc 12″ × 12″ are taken, and a flat resistance



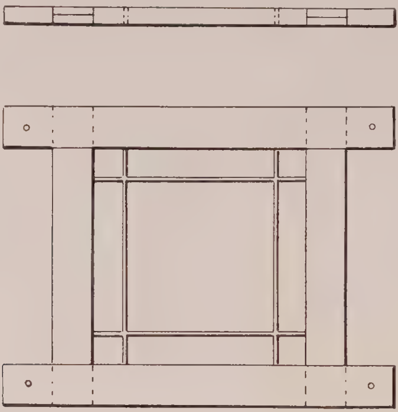
INSULATING FRAMES FOR CONDUCTIVITY TESTS.

Fig. 80.

coil of fine double silk-covered wire wound uniformly over a central 6″ square of one of their faces. The wire is wound non-inductively and secured to the zinc plates by stitches of thread passing through fine holes drilled in the metal. A

[1] See an article by Lamb and Wilson in the Proceedings of the Royal Society, 1899, page 287, and Nusselt in Zeitschrift des Vereins Deutscher Ingenieure, June 1908, page 1003.

photograph of one of these coils is shown on the right of Plate LXVI. Zinc plates prepared in this way are inserted on each side of the slabs of insulation, the fine wire coils being in direct contact with the material to be tested. Thin wood covers are now put on both sides, and the whole is clamped firmly together by four bolts, with wing nuts passing through two skeleton frames of wood, as shown in Figs. 80 and 81. The apparatus is then hung in a vertical plane in a



Frame used for Air Gap Experiments

FIG. 81.

situation screened from draughts and sunlight. The terminals of the heating-net are led away through an adjustable resistance and suitable switch gear to a battery of accumulators. A volt-meter and ammeter are connected up to the circuit, from the readings of which the watts dissipated can be obtained. As the arrangement of slabs is identical on both sides of the heating-net, the heat generated will divide equally, half escaping through one wall and half through the other. The terminals of the resistance of fine copper wire are connected up to a Wheatstone bridge of the stretched-wire type through a system of plugs, which enables the ratio of resistance of either pair of coils to be determined. A general view of the apparatus is shown in Plate LXV.

By assuming a value for the temperature coefficient of the copper wire, of which the coils are wound, the excess of temperature of the inner over the outer faces of the insulating material can be immediately obtained. The system of plugs also allows of the resistance of any one of the four coils being compared with that of a fifth coil situated in the unheated surrounding air, the temperature of which is measured with an ordinary thermometer. This enables the absolute temperature at the inside or outside of either of the slabs to be determined.

Since the coils which give the temperature of the faces only measure 6″ × 6″, while the heating-net measures 12″ × 12″, it is evident that there is a marginal guard-ring of heat flux 3″ wide all round the central area, through

which the heat gradient is determined. As the heating-net is wound uniformly, heat is generated uniformly all over its surface; the sheets of zinc, being also the same size as the heating-net, help to spread the heat flux uniformly and maintain a direction of flow normal to the surface. With slabs of insulating

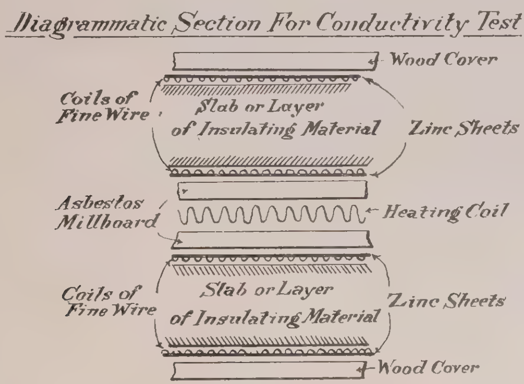


FIG. 82.

material not more than $1\frac{1}{2}''$ thick, there can be hardly any doubt that the flux of heat through the central 6″ square over which the temperature of the faces is determined is uniform, normal to the surface, and of density equal to half the watts dissipated in the heating-net per unit area. With slabs 1″ thick it will be seen that although the total amount of material required for the test is small, the value obtained for the heat conductivity of each slab will really be the average of 36 cubic inches of the material. In all cases the difference of temperature between the faces was measured for each of the slabs, thereby making sure that the heat-flow through each slab was approximately equal, and enabling the average coefficient to be determined for a total of 72 cubic inches of material divided between two separate specimens, although the total number of temperature observations involved is only two, and these can be taken immediately one after the other by simply changing over the plug connexions to the Wheatstone bridge. When the apparatus is once got together, the introduction of fresh specimens is only the work of a few minutes. If it is desired to test some loose material, such as powdered cork or silicate cotton, two more wood frames, similar to those in Fig. 80 are used for retaining it in position.

As soon as the material is in position and the heating coil and fine-wire coils are connected up, a suitable heating current is switched on and the apparatus left until the steady state is attained. The time necessary for this may be anything from 12 hours to two days, depending on the nature of the material and the magnitude of the heating current.

In Fig. 84 are shown the results of a series of tests on boards of yellow pine 1″ thick. The heat escaping, expressed in B.T.U. per square foot per hour, is shown, in relation to degrees Fahrenheit. The B.T.U. per square foot per hour have been arrived at by multiplying the watts dissipated in the resistance by

3·4 and dividing by twice the area of the heating-net. The difference in temperature in degrees Fahrenheit has been obtained by multiplying the percentage increase of resistance between the various coils of fine copper wire found by the Wheatstone bridge by 4·5. Curve (1) shows the mean difference of temperature between the inside and outside faces of the boards in an enclosed test, as shown in the diagrammatic section, Fig. 82. We see that when the temperature difference between the faces is 50° Fahrenheit the number of B.T.U. escaping per square foot per hour is 52. Hence, under the existing temperature conditions, the termal conductivity, defined as the quantity of heat measured in B.T.U., which pass per hour through a cross-section of 1 square foot, when the temperature gradient is 1° Fahrenheit per inch, is 52/50=1·04. It will be noticed that the curve (1), in common with all similar curves obtained for other materials tested, is slightly convex to the temperature axis, thereby confirming Nusselt's result, that the conductivity of heat insulators increases with rise of temperature.

Curve (2) of Fig. 83 shows the difference of temperature between the inside faces of the boards and the external air when the apparatus is arranged so that

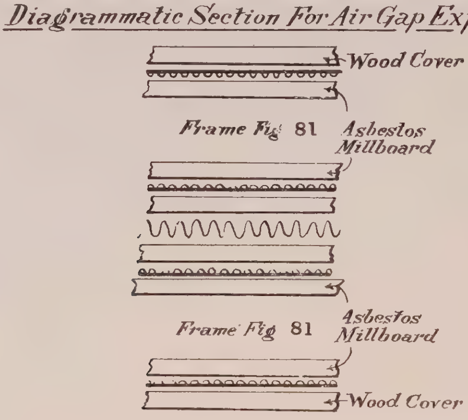


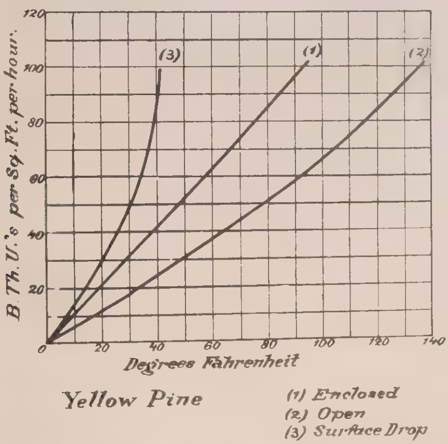
Fig. 83.

the outside surfaces of the boards are uncovered. Curve (3) of the same figure has been obtained by plotting the temperature intercepts between curves (1) and (2) for different heat fluxes, and the abscissæ of this curve accordingly represent the drops in temperature which occur at the outer surfaces. The way in which curve (3) bends up shows how very incorrect Newton's law of cooling becomes as soon as the drop in temperature exceeds 40° or 50° Fahrenheit.

We can now make an attempt to predict the amount of heat that will pass through a partition made of various thicknesses of this material, when certain specified differences of air temperature exist on the two sides. For any definite heat flux, the difference in temperature between the two faces of the partition will be the corresponding abscissa of curve (1) increased or decreased in simple proportion to the thickness; the corresponding abscissa of curve (3) is assumed

to be the drop of temperature at the surface that will occur on each side of the partition. For example, suppose we have a partition of yellow pine 1½″ thick, and the heat flux penetrating it is 40 B.T.U. per square foot per hour, we find—referring to curve (1) of Fig. 84—the drop in temperature in the wood itself must be 1½″ × 38″=57° Fahrenheit, and that the drop in temperature at each face will be approximately the corresponding abscissa of curve (3), viz., 26° Fahrenheit. The difference in air temperature between the two sides of the partition is accordingly (57+2×26)° Fahrenheit=109° Fahrenheit.

A more practical aspect of the same problem is: given the difference in air temperature existing on the two sides of the partition, to find the heat-loss for different thicknesses of wood. The curves in Fig. 85, deduced after the manner indicated above, make it possible to read off the answer to this question at a glance. From the shape of the curves it is evident that after a moderate thickness of wood, increasing the thickness only improves the insulation at a very slow rate. Results from these curves must, however, be accepted with caution, for radiation will differ somewhat on the two sides, due to the different nature of the bodies involved and their difference in absolute temperature. Also, the transfer of heat by air contact will be very sensitive to convection currents, the precise nature of which is difficult to foresee, but will most probably be somewhat different on the two sides. Accordingly, the amount of error involved in assuming that the drops of temperature at the two surfaces are the same, and each equal to the drop found in the laboratory experiment, is not easy to judge.



HEAT DIAGRAM FOR YELLOW PINE TESTS: SQUARE FEET PER HOUR.
FIG. 84.

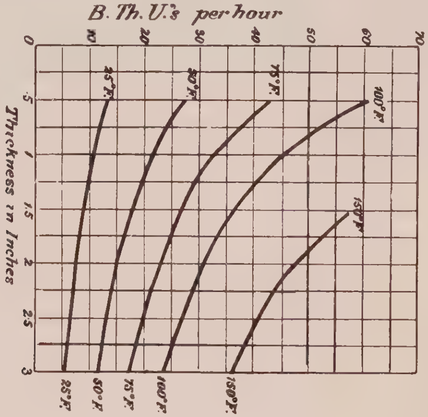
In more usual conditions of cold-storage construction, however, these doubtful surface effects have much less relative importance. Suppose, for instance, that the insulation consists of a layer of silicate cotton 10″ thick confined between wood boards. From Fig. 86 it is seen that a total temperature difference of 100° Fahrenheit (i.e., a temperature gradient of 10° Fahrenheit per inch)

would only produce a heat flux of about 5 B.Th.U. per square foot per hour. With this low density of heat flux, curve (3) of Fig. 84 shows a temperature drop of less than 4° Fahrenheit, so that the combined temperature drop at the two outer surfaces is less than 8° Fahrenheit—i.e., less than 7·5 per cent of the total.

The following table shows the specific gravity and coefficient of heat conductivity as determined by the apparatus described for a number of different materials:—

Material.	Spec. Grav.	Coefficient of Heat Conductivity at 50 to 75° Centigrade.
Yellow pine across grain	0.360	0·13
Teak across grain	0·515	0·23
Expansit Schrot No. I	0·051	0·055
" " No. II	0·049	0·061
Compressed cork slabs	0·166	0·060
Silicate cotton or slag wool	0·330 0·256 0·141 0·113	Mean value 0·07
Asbestos sheet, ½″ thick	1·240	0·25
Asbestos mill-board, ⅜″ thick	1·075	0·14 to 0·1
Air-jacket in the vertical plane, 1″ wide, walls of asbestos mill-board	....	0·26 to 0·31

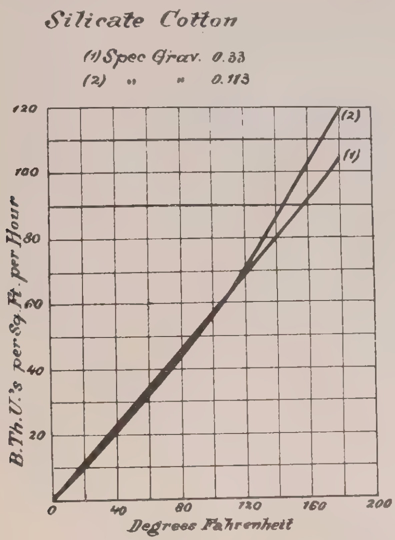
The specific gravity of the loose materials was obtained by weighing the amount introduced into the apparatus. In all cases, except for the asbestos, the



HEAT DIAGRAM FOR YELLOW PINE TESTS: PER HOUR.
FIG. 85.

thickness of which is specifically stated, the tests were made on solid slabs or layers of material 1″ thick. The temperature of the inside surfaces of the insulating material varied from 50 to 75° Centigrade. The atmospheric temperature was about 17° Centigrade. In cases where the increase of conductivity

with rise of temperature was found considerable, values are given for both limits of temperature. To facilitate comparison with the results of Nusselt, the conductivities given in the table have been expressed in kilogramme-calories passing per hour through a cross-section of 1 square metre when the temperature gradient

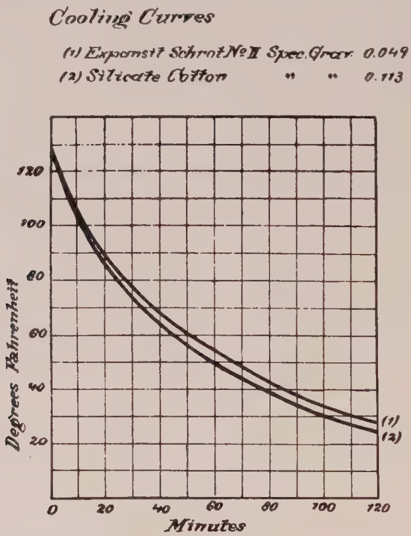


HEAT DIAGRAM FOR SILICATE COTTON: SQUARE FEET PER HOUR.
FIG. 86.

is 1° Centigrade per metre. To convert the conductivities into B.T.U. per square foot per hour for a temperature gradient of 1° Fahrenheit per inch, the figures given in the table must be multiplied by 8·05. Thus for yellow pine, $0{\cdot}13 \times 8{\cdot}05 = 1{\cdot}04$ nearly, as previously obtained from Fig. 85.

The specially prepared cork known as 'Expansit,' for samples of which the author is indebted to Messrs. Grunzweig and Hartmann of Ludwigshafen, is seen to be a wonderfully light and efficient insulator. The material as tested consisted of small granules, but it can also be obtained in block form. When Expansit Schrot No. I was put under the test, the first observations gave a conductivity as high as 0·06, which gradually fell until 0·055 was reached. The reason for this improvement in insulating resistance of almost 10 per cent, was found to be due to the expulsion of moisture, although the granules appeared to be quite dry when first introduced into the apparatus. This instance, typical of many subsequent experiences, serves to show the deleterious effect of moisture on heat-insulators. When the Expansit was removed from the apparatus it was found that water had been driven to the outer surfaces and the granules were all caked together, so that the final result is probably not so good as would have been obtained had the material been dried before it was introduced into the apparatus.

The somewhat higher conductivity of Expansit Schrot No. II, is due to the larger size of the granules composing it. The most efficient grain size is a point of much interest. The heat-insulating effect produced by a porous material is apparently due to the fact that the space which it occupies



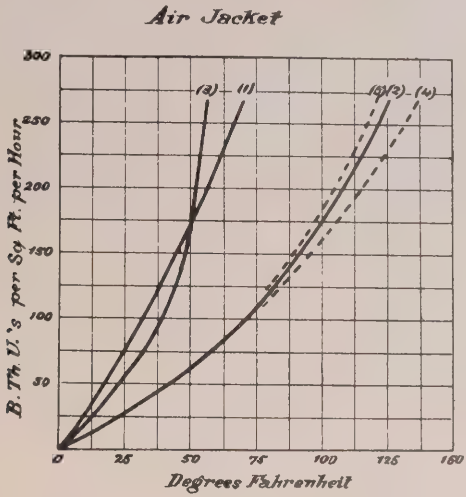
HEAT DIAGRAM FOR SILICATE COTTON: COOLING CURVES.

FIG 87.

consists mainly of air split up into such a fine state of subdivisions that convection is prevented by viscosity. The more minute the pores the more hampered will be the movement of the occluded air; but a limit will be reached when the pores are made so small that the benefit derived from this cause is counterbalanced by the increased conduction of heat that takes place through the substance of the material itself. From the researches of Clark Maxwell and Winkelmann it appears that the conductivity of perfectly still air is only about 0·02, which may be taken as the ideal towards which the conductivity of actual porous insulating material can only approach. The author understands from Professor O. Knoblauch, of Munich, that a conductivity as low as 0·033 has been obtained for Expansit of very fine grain, which is getting very close to the ideal figure.

To test the fireproof qualities of Expansit, a shallow layer of Schrot No. I was put in an open tray and placed on an electric heater. When a temperature of 500° Fahrenheit was reached the material began to smoke. Heating was continued until the temperature rose to 650° Fahrenheit, by which time the material was smouldering briskly, but did not catch fire. The heating current was then switched off and the charred material allowed to cool. A subsequent test showed that the treatment the material had undergone had raised its conductivity about 7 per cent.

Silicate cotton was experimented with in four different densities. Results for the highest and lowest densities, representative of very loose and very firm packing, are shown in Fig. 87. It will be seen that loose packing makes slightly the best insulator for small differences of temperature; but firm packing is much the best when the temperature difference is considerable. On the whole the re-



DIAGRAMATIC SECTION: SQUARE FEET PER HOUR.
FIG 88.

sults indicate that it is advisable to pack the silicate cotton as firmly as possible, especially as this ensures that the material will not afterwards subside, so as to leave holes which cannot afterwards be filled up. After a temperature difference of 120° Fahrenheit the curve of the loosely-packed silicate cotton bends up in a way which resembles the curve obtained for an unfilled air-gap.

Besides having a low conductivity, and apart from considerations of cost, durability, etc., it is desirable that the material employed for insulating cold stores should have a high specific heat; for walls having considerable capacity for heat will keep down the temperature for some time, should the refrigerating machinery be temporarily stopped. The apparatus described above for measuring conductivity is also well suited for getting comparative values for heat-insulators from this point of view. A steady state is established with some specified internal temperature, the heating-current is then switched off and the rate of fall of internal temperature determined by taking readings periodically, the conditions of cooling being in all cases the same. Fig. 87 shows comparative cooling curves obtained in this way for Expansit Schrot No. II and silicate cotton density 0·113. The results show that Expansit is superior from this point of view as well as being a better insulator, in spite of the fact that, volume for volume, it is less than half the weight of the silicate cotton.

Results for asbestos lead one to the conclusion that its value as a heat-insulator is due rather to its fireproof qualities than to its low conductivity, which indeed appears to be no lower than the conductivity of wood.

To make experiments on the conductivity of a simple air-jacket, two double-thicknesses of thin asbestos mill-board were inserted in the positions usually occupied by the slabs of insulating material to be tested; curve (1) of Fig. 88 was obtained with this arrangement. Frames as shown in Fig. 81 were now inserted in the position indicated in the diagrammatic section shown in Fig. 83, so that a central air jacket 9″ × 9″ was introduced on either side, surrounded by a marginal dead air space about 1½″ wide. With this arrangement curve (2) was obtained. Curve (3) was constructed by plotting the intercepts between the curves (1) and (2), and must represent very approximately the difference in temperature between opposite walls of the air-jackets. It is at once evident that an air-jacket of this description is a very poor insulator even for small differences of temperature, and that the conductivity increases enormously as the temperature difference is increased.

Curves (2) and (3) refer to an air-jacket with vertical walls; as convection must have a great deal to do with the transfer of heat from one wall of the air-jacket to the other, it is clear that an air-jacket between horizontal walls will act differently. The effect was tried of turning over the apparatus bodily from the vertical to the horizontal plane. The temperature differences for the jacket that was now uppermost rose from curve (2) to curve (4), while for the jacket that was underneath the temperature differences fell from the curve (2) to curve (5). The explanation of these results appears to be that currents of hot air rising freely from the upper horizontal surface of the apparatus enabled the heat to be carried off with only a small difference in temperature between the top of the jacket and the outside air. On the other hand, the hot air produced by the heat conducted through the bottom horizontal surfaces, instead of being displaced by cold air, remained in contact with the lower surface, with the result that the outside wall of the lower jacket rose in temperature, thereby diminishing the difference in temperature between the two walls of the jacket. The heat conductivity of the two jackets can no longer be calculated, for the ratio in which the total heat dissipated divides itself between the two jackets is no longer known. No doubt by far the greater portion of the heat flux rises vertically through the top jacket.

In conclusion, the author would like to acknowledge his indebtedness to Professor J. R. Henderson, D.Sc., who originally suggested the form of testing apparatus employed.

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